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THE FUTURE OF MAN AS AN INHABITANT OF THE EARTH[1]

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I

DURING the first decade or two of the current century, geologists, astronomers and physicists engaged in many discussions concerning the future of the earth as an abode for life. Some believed that "the end of the world" was relatively close at hand; others, that the prospect for the future was to be measured in terms of hundreds of thousands if not of millions of years. As usual in scientific circles, there has emerged from the conflict of ideas during the years of discussion a general unanimity of opinion, and to-day the geologic outlook for the future of the earth is quite clear.

Since the turn of the century new methods of measuring the length of geologic time have been discovered and applied. New concepts of the nature and sources of energy have been proposed and tested. New data concerning astronomic space and the distribution of the stars have been secured. Innumerable details of earth history have been deciphered to give a trustworthy record of the changes which the earth and its inhabitants have undergone in the past. The key to unlock the secrets of the future is now available in this knowledge of the past, and with our present understanding of the processes of nature that key may be intelligently used. All the evidence combines to lead us unmistakably to the conclusion that for many scores if not for hundreds of millions of years to come the earth will continue to be a comfortably habitable abode for creatures like ourselves.

Surface temperatures of the earth, the most important item in any consideration of its long-range habitability, are determined by the receipt of solar energy distributed through atmospheric agencies. For any given area of land the annual contribution of heat from the earth's interior, hot though it may be, is just about equal to the warmth received from the sun in twenty minutes by an equal area in equatorial latitudes under a clear sky at mid-day. The nineteenth-century picture of an earth, initially fiery hot but progressively cooling so that yesterday it displayed a glacial climate and to-morrow it will be too frigid to support life, may now be thrown into the discard. The earth will "grow old and die" only as a result of failure to receive adequate supplies of radiant energy from the sun. The prospect that the sun will "burn itself out" in a decrepit old age is so remote as to baffle all attempts to date that untoward event even by those who are expert in manipu-

[1] An address delivered under the joint auspices of the American Association for the Advancement of Science and the Society of the Sigma Xi at the Columbus meeting of the association.

lating astronomic figures. Nor is there any likelihood that the space relations between earth and sun will change appreciably within scores of millions of years and put the earth either too close to the sun or too distant from it for comfort.

The lurid pictures of a sudden catastrophic debacle resulting from collision with some other heavenly body—comet, planet, star or what you will—are products of a vivid imagination wholly without foundation in astronomic fact or theory.

The only plausible alternative to the conclusion that earth and sun will continue the even tenor of their ways for an inconceivably long period of time is that the sun will some day imitate the super-novae occasionally detected among the stars and terminate the existence of the entire solar system by a gigantic explosion. Precisely one such super-nova has been observed within the galaxy of the Milky Way and several such in all the other galaxies of stars during the past few decades. The astronomers could therefore calculate for us the chances on a statistical basis that any individual star—the sun, for example—would suffer such a fate within any given period of time. The result would be a figure so infinitesimal as to set at rest the mind of even the most jittery of questioners. Pending the discovery of the kind of premonitory symptoms displayed by stars about to blow themselves to atoms, the best that can be done is to rest content in history. Since the earliest records of living creatures were left as fossils, if not indeed since the earliest sedimentary rocks were formed, the sun has faithfully maintained its energy output within a fairly narrow range and has given no evidence of any fluctuations that might suggest any significant change in its behavior.

The geologist may therefore turn with confidence from the long perspective of geologic past with its one-and-a-half to two billion years of recorded earth history to a similarly long prospect for the future. Time is one of the most overwhelming resources of our universe.

It should not be inferred, however, that the earth will continue in the future to display the same environmental conditions as those which we enjoy to-day. The history of mankind thus far has been enacted against a background that in the full perspective of earth history is truly extraordinary. The geologic period in which we live is a time of unusually rugged and extensive lands with notably varied climate ranging from the glacial cold of Greenland and Antarctica to the oppressive warmth and humidity of certain equatorial regions. Such conditions have apparently recurred many times at long-spaced intervals since the oldest known rocks were formed, but added together the time thus represented can not be as much as a fourth of geologic time. Much more characteristic of earth history as a whole have been the conditions illustrated by those periods when corals thrived in shallow seas occupying the site of Baffin Land and North Greenland, and coal-forming plants flourished on Antarctica. The probability is strong that eventually, say in five or ten million years, the earth will display again the physical conditions of many past geologic periods that were characterized by broad low lands, wide shallow seas and uniform genial climate.

But most of us have a greater interest in the next few centuries than in the subsequent millions of years. Minor changes in climate will doubtless occur just as they have in the last few thousand years. Unfortunately, or perhaps fortunately, there is no basis for prediction concerning their nature, whether for better or for worse. There is really no good reason for referring to the present as "a post-glacial epoch"; it may prove to be an interglacial epoch. But our ancestors weathered ice ages in the past, and presumably we are better equipped for such contingencies than they were. Should the average annual temperature of the earth as a whole be reduced some-

thing like 10° F. and remain at that lower level for a few millennia, it is likely that once more the greater part of Canada, the northern United States and the Scandinavian countries would be buried beneath great ice sheets. But in consequence of the removal of water from the sea as vapor to form the snow to produce the glacial ice, considerable areas now shallowly submerged along the coastlines in middle and equatorial latitudes would emerge as dry land. Indeed, it is likely that the area of land suitable for human abode would be nearly or quite as great at the climax of a glacial period as it is to-day.

By the same token, the disappearance of existing bodies of glacial ice as a result of rapid amelioration of climate in the not-distant future would, if it occurred, be a decidedly mixed blessing. Return to the sea the water now imprisoned in the ice on the Arctic islands, Greenland and Antarctica, without any compensating changes in crustal elevation, and sea level would be raised 50 or 60 feet the world around. Considering the number of people who now work or sleep in buildings in metropolitan communities not over 50 feet above sea level, the importance of such a change is readily apparent.

But from the geologist's point of view these are relatively trivial matters. With due deference to the nature of the climatic variations and geologic changes which are certain to occur in the next few thousand years, there is nothing to be expected from such sources that would seriously deter the human species from maintaining a comfortable existence on the surface of the earth for an indefinitely long period of time—a period to be measured in millions rather than in mere thousands of years.

II

At last, it is generally understood that man is a part of nature. He may be something more than an animal (that depends largely upon definition), but he is none the less truly a part of the animal world. Like the other inhabitants of the earth, man is a product of evolutionary processes operating on this particular planet.

We may be the latest product of the creative forces displaying themselves in the organic development taking place in this particular portion of the cosmos, but we have no reason to assume that we are the last achievement of those forces. Nor does the fact that man has arisen from a lowly origin through processes of evolution validate the optimistic inference that he will necessarily continue his progress to ever higher levels of activity. Evolution does not guarantee progress; it merely guarantees change. The change may be for the better or the worse, depending upon the conditions of time and place and the vitality of the individuals concerned.

The pages of Mother Earth's diary reveal an amazing and thought-provoking record of the progress of living creatures throughout the long eras of earth history. Again and again, in the procession of the living, dynasties of animals or plants have arisen from a humble origin to a position of world supremacy, maintained for a comparatively brief period and then lost forever. Some have disappeared entirely as their paths have led them off into blind alleys. Others have sunk to a low level and have continued a degenerate existence to the present day. A few have given rise to other and more efficient forms of life that superseded their predecessors as leaders in the procession. Gradually we are discovering some of the reasons for success and failure along the path of life. Beyond question, man may profit from these experiences of the past, if he uses the intellectual and moral resources which are available for him.

From the point of view attained through knowledge of geologic life development, man has to-day a unique opportunity to gain continuing security for himself and his progeny on the face of

the earth, but whether or not he takes advantage of that opportunity is to be determined largely by himself. So far as we can tell, man is the first animal possessing the power to determine his own evolutionary destiny, but there is nothing in the record which guarantees that he will use that power wisely.

The animal species that in the past have been able to maintain their existence for more than two or three million years are relatively few in number. Most of them were comparatively simple types belonging to the less highly organized branches or phyla of the animal kingdom. Many were inhabitants of the sea where environmental conditions were remarkably stable throughout long periods of time. Among placental mammals, the major subdivision of the vertebrates to which man belongs, there is no similar record of longevity. Except under extraordinary conditions of geographic isolation, no species of placental mammal has persisted more than two or three million years. No matter how successful it may have been temporarily in multiplying and spreading over the face of the earth, each has become extinct in a geologically brief span of time. Perhaps a half million years might appropriately be taken as the average "life" of a species in this group of highly organized and notably complex creatures.

But extinction does not necessarily mean failure; it has frequently indicated the acme of achievement. For example, some of the now extinct three-toed horses and four-toed camels passed on "the torch of progress" to their descendants, the one-toed horses and two-toed camels, and thus gained long-continuing security for their kind.

What, then, does the future hold for mankind? Genus *Homo* has already existed for three or four hundred thousand years; the species *Homo sapiens* has about fifty thousand years to its credit. If the average applies, we may expect nearly or quite a half million years more of existence for our kind and then either oblivion as we reach the end of a blind alley or progressive development into some type of descendant better adjusted than we to the total environmental factors of the time.

III

But does the average apply? Must man exit from the scene through either of the doors, that which closed behind the dinosaurs and titanotheres or that which opened before the three-toed horses and notharctines?

Most creatures have gained security by specializing in adjustment of structure and habit to particular environmental conditions, whereas man is a specialist in adjustability of structures and habits to a variety of environments. No other vertebrate can live as can he on Antarctic ice cap, in Amazonian jungle, beneath the surface of the sea, or high in the air.

Furthermore, man is the world's foremost specialist in transforming environments to bring them within the range of his powers. Far more efficient than the beaver or the mound-building ant, he drains the swamp, irrigates the desert, tunnels the mountain, bridges the river, digs the canal, conditions the air in home, factory and office.

As a matter of fact, adjustability to environment is accomplished more by controlling surroundings than by modifying internal organs or essential functions of the body. When we ascend with Major Stevens into the stratosphere, or dive with Dr. Beebe 500 fathoms deep off Bermuda, or live with Admiral Byrd through the long night of Little America, we take along with us a sample of sea-level atmosphere and temperate climate which is our real environment in a situation otherwise unbearable. Fur-lined parkas and tropical linen suits are but a medium for ensuring an immediate environment as nearly as possible like that of middle latitudes when living in polar or equatorial surroundings.

But regardless of interpretation of

procedure, the result is clear. Man has placed himself in control of external conditions to an extent immeasurably greater than has any other creature. He has practically "drawn the teeth" of environment.

Although we know little of the details, it is certain that most of the creatures of the past who "have had their day and ceased to be" were forced into extinction by changes of one sort or another in their environment, changes which came with such relative speed that they were unable to make adjustment to them in time. Man need have no fear on that score.

IV

It is, however, immediately apparent that man's conquest of his surroundings has resulted from his clever use of things. Unless there is a ceaseless flow of cotton, flax and wool, of coal, iron and petroleum, of copper, lead and tin, from ground to processing plant to consumer, he becomes a puny weakling. It is because he uses certain resources provided by his environment that he is freed from slavery to his environment. Are these resources adequate to keep him supplied with what he needs to maintain indefinitely the sort of existence to which he has accustomed himself?

There are two fundamental sources of the goods and the energy which man uses in the grim business of securing the sort of living which he apparently desires. On the one hand there is the farm and the waterfall, on the other there is the mine and the quarry. Things which grow in the field or forest, and power produced by falling water are in the category of annual income. Now that scientific research has made available the limitless quantity of nitrogen in the air for use as fertilizer, the resources of the plant and animal kingdoms are renewable; we use them, but we need never use them up. In startling contrast the resources of the mineral kingdom are non-renewable; they are in the category of accumulated capital. Petroleum and coal, copper and iron, lead and vanadium, these and many other prerequisites of modern civilization have been accumulated by nature through hundreds of millions of years of geologic activity. Thanks to scientific research, man is exhausting that store of mineral wealth in a few hundred, or at most a few thousand, years. That inescapable fact is at rock bottom one of the most fundamental causes of economic distress, of war between nations and of strife between classes.

Fairly accurate estimates of the world stores of many non-renewable resources are now available. Take petroleum as an illustration. The known available reserves of petroleum beneath the surface of the United States total at present approximately 17 billion barrels.[2] Experts differ in their guesses as to the quantity of petroleum that may be discovered in the future in areas that have not yet been adequately explored with the drill or in known fields by discovery of deeper reservoirs not yet reached by the deepest wells in those fields. There are also many varying shades of optimism and pessimism concerning the possibility of increasing materially the percentage of recovery of the oil present in a reservoir rock when penetrated by drilling operations. Estimates of the quantity to be added to our petroleum reserves from these two sources range from 7 or 8 billion barrels to 15 or 20 billion. I would incline toward the larger figures, considering them as maxima that are extremely unlikely to be exceeded. On that basis, the present store of available petroleum beneath the surface of the United States is 25 to 35 billion barrels. That is only about thirty times the annual domestic consumption of petroleum in recent years. The average annual production of petroleum in the United States during the five years from 1934 through 1938 was almost one

[2] *American Petroleum Institute Quarterly*, 9: 2, 7, 1939.

billion, one hundred million barrels,[3] and the 1939 production exceeds one and a quarter billion barrels. At the present rate of withdrawal, the domestic stores of this essential raw material would, therefore, be exhausted in less than a third of a century.

Data are not nearly so precise for the majority of foreign countries as for the United States. It is, however, fairly safe to conclude that the world stores of petroleum will last only something like 75 years at the present rate of withdrawal. With the possible exception of Mexico, no other country has been as successful as the United States in the attempt to exhaust its petroleum resources in the shortest possible period of time, but rapid progress toward that result is now being made in many regions.

Lest we become too pessimistic in response to such unwelcome figures, we should promptly note that substitutes for petroleum are already known. Gasoline, fuel oil and lubricating oil can now be manufactured from coal and other rocks rich in carbon, by processes of hydrogenation and polymerization. These are expensive processes, and their products can not now compete with the products from petroleum even in countries far removed, both geographically and psychologically, from the more productive oil fields.[4] They will, however, come into use more and more in the next few decades.

Enough bituminous and sub-bituminous coal is known to be available within the United States to meet the present annual demand for coal, plus enough to manufacture gasoline and fuel oil in sufficient quantity to meet current demands for at least two thousand years. In addition there is enough oil shale—a rock rich in carbon but containing little or no oil—to meet present needs for petroleum products for at least three or four thousand years.

Although petroleum affords an excellent illustration of the relation of non-renewable resources to the activities of man, it is by no means typical of the items comprising nature's accumulated capital. For nearly all the important non-renewable resources, the known world stores are thousands of times as great as the annual world consumption instead of less than a hundred times. But for the few which like petroleum are not known to be available in such vast quantities, the story is much the same. Substitutes are already known, or potential sources of alternative supply are already at hand, in quantities adequate to meet our current needs for at least two or three thousand years. There is, therefore, no prospect of the imminent exhaustion of any of the essential raw materials, so far as the world as a whole is concerned, provided our demands for them are not multiplied rapidly in the future.

That, of course, raises another question. Will the demand for non-renewable resources increase materially in the future and thus hasten their exhaustion? Recalling the fact that the human population of the earth has increased almost five-fold in number in the last three hundred years, we might well be fearful on that score. The study of current population trends, however, makes it readily apparent that the next few hundred years will by no means duplicate that record of the past. If present trends continue, the all-time maximum population of the United States will be attained about the year 1970 and will total little more than 150 million souls.[5] Thereafter, except for possible influx of immigrants from other countries, no further increase in numbers is to be expected.

[3] Statistics from *Minerals Yearbook*, published annually by the United States Bureau of Mines.

[4] K. C. Heald, "Technology and the Mineral Industries," WPA National Research Project, Report E-1, pp. 27–31, 1937.

[5] Thompson and Whelpton, National Resources Committee, Population Statistics, Vol. 1, "National Data," p. 9, 1937.

Accurate figures are available for only a few other countries, such as England, France and Germany, but there is a strong probability that the all-time maximum for the "white" races will be reached during the last third of the twentieth century and for the entire population of the earth before the end of the twenty-first century. Although the human family has doubled its numbers since 1860, it is extremely unlikely that it will ever reach twice its present number of approximately 2 billion. The pressure of demand for non-renewable resources will not, therefore, become acute because of the increase in population in the near future. Mother Earth is a very wealthy benefactress, and our heritage of physical resources is far greater than ordinarily supposed.

There is, however, another reason why current consumption of non-renewable resources can not be taken as the basis for computing the "life" of such stores of basic materials. The demand for automobiles, telephones, radios, airplanes, zippers, is to-day very unevenly distributed. Only a small fraction of the human population uses such things in any large amount. Other peoples are beginning to demand them and will do so increasingly as they become acquainted with the "benefits of civilization." In a few decades, unless we return to savagery, the world demand for many non-renewable resources will be twice or thrice that of to-day.

Taking all these things into consideration, it would appear that world stores of needed natural resources are adequate to supply a basis for the comfortable existence of every human being who is likely to dwell anywhere on the face of the earth for something like a thousand years to come.

Even so, there may be found here an excuse for the policy of "grabbing while the grabbing is good," which motivates many individuals and nations at the present time. That excuse might, of course, be offset by the suggestion that there is no need to take thought for a morrow a thousand years hence, if we have any respect for the ingenuity of our remote offspring. There is, however, another phase of current trends in human history that should not be overlooked in this connection.

One hundred years ago, something like 80 per cent. of all the things man used had their source on farms; most of the energy used to do the work of the world came from the muscles of living beings and from falling water. To-day only about 30 per cent. of the things man uses come from things that grow; most of the energy with which work is done comes from petroleum and coal. For a century or more, the policy has been to use relatively less of the annual income and more and more of the stored capital.

Now comes the change. Automobile steering wheels are made from soybeans; piano keys from cottage cheese; innumerable articles fashioned of plastics are produced in part from corncobs and alfalfa; multitudinous metal and rubber substitutes are synthesized from various farm crops. Energy is transmitted at high voltages for hundreds of miles from hydro-electric turbines. A considerable portion of the annual budget for research is being devoted to progress in the direction of using more of the renewable resources—man's annual income, and less of the non-renewable resources—nature's stored capital.

What this new policy will mean is readily apparent. With progress along such lines, the pressure for political control of metalliferous ore deposits, coal fields and oil pools is lessened. Much of the physical basis for international jealousy is removed. At last the intelligence of science may make it truly practical to beat our "swords into ploughshares, our spears into pruning hooks."

Again comes the insistent question from the pessimistic critic. Is there land enough? Is there sufficient fertile soil to provide adequate food and in addition the plant materials for the ever-

expanding chemical industries? And again we hear the same reply. Yes, there is enough and to spare. J. D. Bernal computes from apparently valid data that the cultivation of two billion acres of land by the methods now in vogue in Great Britain would provide an optimum food supply for the entire population of the earth. "Two billion acres is less than half the present cultivated area of four billion, two hundred million acres, itself hardly 12 per cent. of the land surface of the earth."[6] And in this calculation no account is taken of the increased yields that may confidently be expected from the continuing research of agronomists, plant breeders and experts in animal husbandry, not to mention recent developments in the new science of the soil-less growth of plants. Evidently, the predictions of Malthus notwithstanding, mankind need have no fear that increasing populations will place an impossible burden upon the available sources of food. Human ingenuity, intelligent use of renewable resources, wise adjustment of structures and habits to environmental conditions, seem competent to dispel that dread shadow.

But these optimistic conclusions concerning the relation of man to the nonrenewable and renewable resources essential for comfortable existence are based upon world statistics. Obviously, they do not apply with equal force to the economy of individual nations. No nation, not even the Soviet Union, Brazil or the United States of America, embraces within its political frontiers a sufficient variety of geologic structures to give it adequate supplies of all the various metalliferous ores necessary as raw materials for modern industrial operations. The United States, for example, must import nickel, tin, antimony, chromium and platinum if American manufacturers are to use those metals in the fabrication of articles essential to what we are pleased to call the civilized way of life.[7] Likewise, no nation enjoys a sufficient variety of climatic conditions to permit all kinds of foodstuffs to be grown on its farms and fields or gathered from its forests, and to allow the growth of all the various plants contributing raw materials to industry. The United States, again the most significant example for us, is forced to import all the bananas, coffee, tea, camphor, coconuts, flax, jute, quinine, rubber and shellac consumed in this country, either from foreign countries or its own over-seas possessions.[8] It is entirely possible that, within a few decades, substitutes of domestic origin may be available to take the place of many, or even all of such commodities or that plant breeders and agronomists may find a practical way of extending the geographical limits of some of the plants whose products are considered essential so that any nation occupying a large fraction of any continent may actually be self-sufficient. But for the present and probably for a long time to come it is evident that every nation is dependent upon many other nations for the raw materials that it needs for its own industrial prosperity.

Perhaps the most important fact concerning the life of man to-day is this fact of interdependence. No nation, community or individual can gain any lasting measure of security without taking that fact into consideration. The resources that man must utilize, if he wishes to escape the fate of his less intelligent relatives now known only by their fossil remains, are unevenly distributed and locally concentrated. The techniques of discovering and utilizing them are now fairly well known, but satisfactory procedures for making them and their products available to all members of the human family are not close at hand.

The very solution of the physical problems which man encounters in his attempt to maintain his foothold upon the

[6] J. D. Bernal, "The Social Function of Science," p. 347, New York, 1939.

[7] Brooks Emeny, "The Strategy of Raw Materials," p. 26 and chart facing p. 29, New York, 1937.

[8] *Ibid.*, pp. 26–37.

earth brings him all the more forcefully into bruising contact with psychical and spiritual problems that must also be solved if he is to continue his existence on this planet. The critical question for the twentieth century is: How can two or three billion human beings be satisfactorily organized for the wise use and equitable distribution of resources which are abundant enough for all but are unevenly scattered over the face of the earth? Clearly, the future of man depends upon finding and applying the correct answer to that specific but far-reaching question.

Man is not only a specialist in the art of coordinated activity, but the trend toward organization is recognizable in the entire development of cosmic administration. Electrons, neutrons and protons are organized into atoms, atoms into molecules, molecules into compounds; some of the compounds prove to be cells, and these are organized to form individual plants and animals. Latest of all in the history of creative evolution certain individuals have been organized into societies. Transcending all that has gone before is the development of human society, obviously the most difficult, but at the same time potentially the most glorious organization yet attempted.

Two antagonistic alternatives present themselves as possible bases for this organization. The issue between the two has never before been so clearly drawn as it is to-day. The social group, whether it be the family, the industrial or commercial company or the political unit, may be organized on the principle of regimentation, or it may be developed according to democratic principles. Both methods are being tried under a variety of conditions, and each has something to be said in its favor. But both can not be equally conducive to the continuing existence of mankind. One or the other must be selected as the basis for the future security of man.

If regimentation be the choice, then the great mass of humankind must be trained for obedience—blind, unquestioning, but superbly skilful obedience. The educator becomes the intellectual and spiritual counterpart of the drill-sergeant in the army. This is no menial task, nor is its objective a mean one. Skill is a commodity of which there is never likely to be an oversupply. On the other hand, if democracy be the choice, the great mass of humankind must be trained for wise, self-determined cooperation. Precisely those qualities of mind and heart which have long been extolled in Christian doctrine must be developed to the fullest possible extent. Not only skilfulness but also the ability to govern oneself, the eternal prerequisite for freedom, must be developed in each member of the group.

In so far as physical existence is concerned, there would seem to be little or no choice between these alternatives. Perhaps, human nature being what it is to-day, the regimentation of society may temporarily be the more efficient method. But the full circle of organic law embraces more than mere existence. From the continuity of the evolutionary process, there has emerged a creature who is aware of vivid values in life, that may be found beyond the goods necessary for comfortable existence. Ideas and ideals are powerful determining factors in the world to-day, and amongst them the ideal of freedom for the individual in the midst of social restraint is the most vital and compelling of all. Though it baffle our scientific tools for measurement, it is none the less a reality.

It is in the yearning for freedom, the love of beauty, the search for truth, the recognition of moral law and in the awareness of spiritual forces that human nature is distinguished from all other sorts of nature. Man shares with other animals the need for satisfactory economics, for adequate food and shelter, for the goods essential to existence, but his needs transcend these physical factors because his nature differs from theirs. Probably nine-tenths of all the words that have been used since the dawn of speech in reference to "human nature"

have referred to those elements in the nature of man which are shared with other animals rather than to those which are man's unique possession. It would be far better to concentrate upon the latter and thus to distinguish human nature from animal nature.

Regimentation may be good for man as an animal; through that type of social organization his need for goods may be efficiently supplied. But regimentation is certainly not good for human nature as thus distinguished. Experience verifies what wisdom foresees; regimentation stultifies the spirit, destroys personality, standardizes thought and action. Worst of all, regimentation means stagnation of the creative process and, as we have seen, stagnation among the more complexly organized vertebrates has led inevitably to extinction. If man attempts to live by bread alone, mankind commits collective suicide. Apparently the best and perhaps the only chance for mankind to succeed in the quest for security is through progress in the art of living on a high spiritual plane rather than through exclusive attention to the science of existence on a purely physical level.

V

To put this same thought in more specific terms, it means that coordinated activity directed toward efficient organization of individuals must become cooperative activity directed toward the enrichment of personality within an efficiently organized society. This requires both intelligence and good will.

Fortunately, these characteristics are uniquely developed in the species of placental mammal with which we are preeminently concerned. Man is a specialist in the use of both. The trend of the past five thousand years may well continue, despite numerous temporary setbacks, throughout the next few centuries at least.

It is sometimes suggested that because man has specialized in brains, brains may cause his downfall, just as presumably the overspecialization in external armament contributed to the downfall of certain herbivorous dinosaurs. That argument by analogy is, however, heavily punctuated with fallacies. There is as yet no evidence that mankind is weighted down with a superabundance of intelligence. On the contrary, it is failure to act intelligently that endangers individuals and groups in the midst of competition. To see in advance the remote consequences of contemplated action is an ability that ought to be increasingly cultivated rather than scouted as a menace.

There seems to be no good reason why a sound mind should not be accompanied by a sound body. If the number of psychopathic individuals is increasing in this high-speed, technologic age, it is a challenge to be met not by bemoaning the imminent collapse of civilization but by intelligent adjustment of habits and activities to the new demands of the new times.

Once the commitment is made to the belief that the cooperative way of life offers the best chance for the future security of man as an inhabitant of the earth, the need is greater for intelligence to be used as a guide for good will, rather than for good will to be applied as a brake on any possible increase in intelligence.

The roots of self-centered individualism may be traced backward for at least six hundred million years in the record of geologic life development, whereas our heritage of social consciousness dates from a time only about sixty million years ago when gregarious instincts became clearly evident among placental mammals. That trend is, however, especially apparent in the group from which mankind has stemmed.

Man is still in the stage of specific youth. His "golden age," if any, is in the future rather than in the past. Human nature is still sufficiently plastic and pliable to permit considerable change, notably in this important area of attitudes and relationships wherein the in-

crease of good will as a motive for action seems most likely to result in beneficial adjustments to the new factors in the environment.

In thus seeking a satisfactory coordination of intelligence and good will, it becomes necessary for research scientists to give more thought than has been customary in the past to the social consequences of their work. They share with statesmen, politicians, educators and all molders of public opinion the responsibility for determining the uses to which the new tools provided by scientific research are put. As scientists they should continue to seek truth regardless of its consequences and to increase human efficiency in every possible way, but as members of society, as individual representatives of a species seeking future security as inhabitants of the earth, they must also do their utmost to ensure wise use of knowledge and constructive application of energy.

There is a real difference between the so-called "social sciences" and the "natural and physical sciences" that has an important bearing here. It is not that there is anything "unnatural" about the social sciences. Man is a part of nature, and the study of human society is just as truly "natural science" in the real sense of the term as any other study. The difference arises from the peculiar factors and particular functions pertaining to the cooperative way of life. Whereas the scientific use of things may be achieved through the efforts of a very small minority of the citizens, provided with adequate facilities for research, the scientific organization of society in a democracy can be achieved only when the majority of its citizens have the scientific attitude toward social problems and act in accordance with that attitude of mind. In other words, only a few physicists, chemists and technologists are required for the mastery of our physical environment, but for victory in the struggle with ourselves every man must be his own sociologist.

Although this places upon the forces of education a Herculean task, it is not nearly so impossible an assignment as at first glance it might appear to be. In the first place, the responsibility upon the individual citizen is rarely that of designing a new social structure or charting a new program for society. Almost invariably it is his duty merely to select from many plans, programs or proposals the one that seems to him most likely to produce the most desirable results for all concerned. In the second place, scientific habits of mind have already been developed to a greater extent than is ordinarily recognized. The garage mechanic attacks the problem of a balky automobile in a truly scientific manner. The salesman uses psychology in planning his approach to a difficult prospect. The housewife thinks scientifically when about to concoct a new dessert or redecorate the living room. In most cases, it is only necessary to apply in the area of social relationships the same habits of mind that have been followed in the area of individual behavior.

VI

In conclusion, the outlook for the future of man as an inhabitant of the earth is far from pessimistic. If certain tendencies already developing are encouraged and certain resources already available are capitalized to the full, there is good reason to expect that mankind will maintain existence and even live happily for an indefinitely long period of time. The opportunity is his to demonstrate the intrinsic worth of biologic phenomena and thus to justify the vast expenditure of time and energy involved in organic evolution. With greater emphasis upon the development of intelligence and good will, he may achieve that which the temporarily triumphant dynasties of the past have failed to achieve. Thus the geologist may turn from the long perspective of geologic history to the enticing vista of the geologic future of earth and man with high hope and even with confident assurance.

THE ROLE OF CHANCE IN DISCOVERY[1]

By Dr. W. B. CANNON

GEORGE HIGGINSON PROFESSOR OF PHYSIOLOGY, HARVARD MEDICAL SCHOOL

In 1751 Horace Walpole, the English statesman and diplomatist, wrote a letter to his friend, Horace Mann, in which he proposed adding a new word to our vocabulary, "serendipity." The word has not had large usage. It is not commonly found in dictionaries of the English language. When I mentioned "serendipity" to one of my acquaintances and asked him if he knew the meaning, he suggested that it probably designated a mental state combining serenity and stupidity! He was mistaken.

Walpole's proposal was based upon his reading of a fairy tale, entitled "The Three Princes of Serendip." Serendip, I may interject, was the ancient name of Ceylon. "As their Highnesses traveled," so Walpole wrote, "they were always making discoveries, by *accident* or *sagacity*, of things they were not in quest of." When the word is mentioned in dictionaries, therefore, it is said to designate the happy faculty, or luck, of finding unforeseen evidence of one's ideas, or with surprise coming upon new objects or relations which were not being sought. In the progress of man's adjustment to the world in which he lives there have been many instances of serendipity.

Probably the most astounding instance of accidental discovery in history was the finding of the western hemisphere by Columbus. He sailed away from Spain firm in the faith that thus he would learn a shorter route to the East Indies and, quite unexpectedly, he encountered a whole new world. It is noteworthy that he was not at first aware of the significance of what he had found. Indeed, it has been said that he did not know where, in fact, he was going, nor where he was when he arrived, nor where he had been after he returned, but nevertheless he had had one of the most remarkable experiences of all time. The important matter is that he did realize that it was a remarkable experience and followed it by making other voyages and thereby extended his knowledge of what he had done and laid a course which others might follow. Such consequences have been common when accident has been favorable to a seeker after new things and the adventure has been fruitful.

In the records of scientific investigation there are many instances of this sort of happy use of good fortune. Consider for a moment the source and the development of our acquaintance with electrical phenomena. It is reported that some frog legs were hanging by a copper wire suspended from an iron balustrade (note the two different metals, copper and iron) in the Galvani home in Bologna; they were seen to twitch when they swung in the wind and happened to touch the iron. Whether the twitching was first noted by Luigi Galvani, the anatomist and physiologist, or by Lucia Galvani, his talented wife, is not clear. Certainly the accidental occurrence was not neglected, for it was the beginning of a long series of researches by Galvani into the electrical manifestations of living tissues—researches which have preserved Galvani's name in the terms "galvanize" and "galvanism." And it also led to experiments by Volta on the production of electric currents by contact of two dissimilar metals, and thus to the invention of the electric battery—experiments so fundamentally important that Volta's name is retained in the daily use of "volt" and "voltage" in speaking of

[1] An address delivered at a meeting of the American Science Teachers Association, Columbus, Ohio, December 28, 1939.

electrical potential. Such was the origin of the telegraph and, indirectly, of the telephone, radio-broadcasting and the promise of practical television. And such also was the origin of our knowledge of animal electricity which we now use to tell the condition of the heart muscle, because every heart beat sends forth an electrical wave in the body of each of us, a wave which has an altered form when the heart is injured; and the animal electricity which we are beginning to use to learn about conditions in the brain, because of the rhythmic electrical pulsations which delicate instruments, applied to the surface of the scalp, can reveal as typical activities of that wonderful organ in various conditions of rest and activity, health and disease.

Even in the growth of electrical science serendipity has played important roles. It was by pure chance that the mysterious relation between electricity and magnetism was discovered. The Danish physicist, Oersted, at the end of a lecture happened to bring a wire, which was conducting a strong current, to a position above and parallel to a poised magnetic needle. Previously, and by intent, he had held the wire perpendicularly above the needle, but nothing happened; now, however, when the wire was set horizontally along the needle's length, he was astonished to note that, without any visible connection, the needle swung around until it was almost at right angles to its former position. With quick insight he reversed the direction of the current in the wire and found that the needle then deviated in the opposite direction. Later, when clearly understanding the situation, Faraday proved not only that an electric current in a wire can move a magnet, but also that a moving magnet can cause a current to appear in a wire. From these trifling and casual incidents has gradually evolved our vast modern electrical industry—its immense generators, its ingenious devices for distributing extensively over great areas the power which provides innumerable conveniences for human service—light in dark places, a cooling breeze on a summer day, heat for our morning toast, sparks in motor cylinders, the automatic management of complex machines, safety at sea, and what not else that is helpful in our daily lives. When we consider the prodigious and intricate involvement of electricity in the affairs of mankind throughout the world, Galvani's frog legs may be regarded almost as important as the caravels of Columbus.

In the biological sciences serendipity has been quite as fruitful as in the physical sciences. May I call your attention to some instances. The eminent French physiologist, Claude Bernard, had the idea that the impulses which pass along nerve fibers set up chemical changes which produce heat. About the middle of the last century he measured the temperature of a rabbit's ear, and then severed the nerve which delivers impulses to that structure, expecting, of course, in accordance with his theory, that the ear, deprived of nerve impulses, would be cooler than its mate on the other side. To his great surprise it was considerably warmer! Without knowing what he had done, he had disconnected the blood vessels of the ear from the nervous influences which normally hold them moderately contracted, and thereupon the warm blood from internal organs flushed through the enlarged vessels in a faster flow. Thus by accident appeared the first intimation that the passage of blood into different parts of the body is under nervous government—the most significant advance in our knowledge of the circulation since Harvey's proof, more than 300 years ago, that the blood does, indeed, circulate.

Another striking instance of accidental discovery has been described by the investigator himself, Charles Richet. It was concerned with that peculiar sensitiveness toward certain things—such as white of egg, strawberries, ragweed pol-

len and numerous others—*anaphylaxis* or *allergy*. It commonly results from an initial exposure to the substance which later becomes poisonous. The phenomenon had been noted incidentally before Richet's time, but because it did not receive attention it was virtually unknown. In his charming little book, "Le Savant," he has told the story of how, quite unexpectedly, he happened upon the curious fact. He was testing on a laboratory animal an extract of the tentacles of a sea anemone in order to learn the toxic dose. When animals which had readily survived that dose were given, after a lapse of some time, a much smaller dose (as little as one tenth the original), he was astounded to find that it was promptly fatal. Richet declares that at first he had great difficulty in believing that the result could be due to anything he had done. Indeed, he testifies that it was in spite of himself that he discovered induced sensitization—that he would never have dreamt that it was possible!

An accident may be the occasion for scientific advances because of the serious problem which it presents. Let me cite a striking example. No one anticipated that the polishing of rice would be harmful. Yet removal of the covering from the kernels resulted in tens of thousands of victims of the disease, beri-beri, and in immeasurable sorrow and distress. As Mathews has pointed out, however, the study of beri-beri, thus unwittingly induced, revealed not only the cause of that disease but started exploration in the whole realm of deficiency diseases as well, and drove investigators to the discovery of some of the most intimate secrets of cellular processes.

A quite recent instance of serendipity was the finding of vitamin K, lack of which deprives the blood of an essential element for its coagulation. Dam and his collaborators in Copenhagen were working on sterol metabolism in chicks. They noted that the animals on the restricted diet often exhibited extensive internal hemorrhages, subcutaneous and intramuscular. When the diet was changed to seeds plus salts, the hemorrhages failed to occur. By critical tests the disease was proved not to be due to lack of any previously known vitamin, but to lack of a specific antihemorrhagic agent, contained in hog liver fat, certain vegetables and in many cereals. This agent, vitamin K, is reported to be an important factor in surgery. Patients afflicted with obstructive jaundice can be relieved by an operation, but unfortunately in that condition their blood may clot very slowly and therefore they are in danger of disastrous bleeding. This danger can now be readily obviated by feeding vitamin K (with bile salts), for it restores to an effective concentration the deficient element of the clotting process—a happy benefit to human beings coming from a chance observation on chicks.

There are many other noteworthy instances of serendipity which I might detail to you; among them Nobel's invention of dynamite, Perkin's stumbling upon the coal-tar dyes and Pasteur's finding that a vegetable mold caused the watery solution which nurtured it to change the light rays as they passed through. Dynamite placed gigantic powers in the hands of man; the coal-tar dyes have fundamentally affected such varied activities as warfare, textile industries and medical diagnosis, and Pasteur's casual observation has developed into an immense range of chemical theory and research.

Three legends of accidental intimations which led to fresh insight will allow me to introduce the next point which I wish to emphasize—the importance of the prepared mind. It is said that Archimedes had the idea of specific gravity suggested to him while noting by chance the buoyancy of his body in water. And we have all heard the tale that Isaac Newton was led to the concept of a universal law of gravitational force when he saw an apple fall from a tree as he lay

musing on the grass in an orchard. Of similar character is the report that the possibility of the steam engine came to the mind of James Watt when he beheld the periodic lifting of a tea-pot lid by the pressure of the water-vapor within the pot. Now, many a man floated in water before Archimedes, apples fell from trees as long ago as the Garden of Eden (exact date uncertain!), and the outrush of steam against resistance could have been noted since the invention of fire. In all three instances a long time passed before the significance of the event was perceived. Obviously, a chance discovery not only involves the phenomenon to be observed, but also the appreciative and intelligent observer.

It was in recognition of this fact that the wise and discerning dictum of Pasteur is displayed in prominent letters in the corridor of the students' dormitory of the Harvard Medical School—"Dans les champs de l'observation le hazard ne favorise que les esprits préparés." In the fields of observation chance favors only the minds which are prepared. That expression has important implications.

In the course of our human experience no one can tell what new circumstances may arise, nor can one predict the moment of their arrival. To-morrow opportunities may appear the seizure of which or the neglect of which may have long-lasting and fateful consequences. There is a tide in the affairs of all of us which "taken at its flood leads on to fortune"—and not taken may lead on to misfortune. In other words, the unexpected is continually happening in our lives, much as it happens in the realms of exploration and scientific research. Chance throws peculiar conditions in our way and, if we have alert and acute vision, we see their importance and use the opportunity which chance provides.

What are the prerequisites favorable for making greatest use of a novel occasion when it arrives?

First of all, if we are to benefit by such an occasion for securing fresh insight and enlarging our experiences in untried directions we must be well equipped with knowledge of the past. Only when we know what has already been done by others who have gone before us can we judge the present scene. The word "research" is commonly employed to indicate scientific investigation. Why is not the word "search" quite as exact? The "re" in "research" implies that the investigator studies carefully the methods and results of earlier investigators and *looks again* at the problems which they strove to solve, with the advantage now of possessing all accumulated previous knowledge, ready for the flashing of an illuminating idea. That is the method of discovery in its most elaborate development. We do not need to go to such lengths, however, in order to enjoy in a mild way the satisfaction of bringing to bear, in unanticipated circumstances, the stored memories of bygone events. A historical reference in speech or literature, or a name in a poem, is endowed with larger significance if we contribute to it rich associations from our own past. "In Xanadu did Kubla Khan a stately pleasure-dome decree" are lines which do not demand information in order to appreciate their musical beauty, but if one knows the story of Kubla Khan as the poet knew it, and is acquainted with oriental magnificence, the words take on an enlarged and special meaning. Furthermore, with the mind prepared there is always the favoring possibility of continuing enrichment as one grows older. One brings to the reading of history and literature, to the unpredictable incidents of travel, to the flashing moments of conversation, and to the varied adventures of the passing years a substantial basis on which can be gradually developed manifold interests and the happy relations of the individual to his fellows and to his surroundings.

In the life of every investigator who

has had much experience, occasions of happy chance are likely to be found. During the past four decades in my own labors instances of such good fortune have several times occurred. When a man has passed his sixtieth year, it is said, he may at last be permitted, without censure, to engage in reminiscence. Perhaps you will be tolerant, therefore, if I recount to you an example of serendipity that fell to my lot. After all, an investigator is not taking undue credit to himself when he calls attention to the fact that results which he has obtained in his researches have depended on a fortuitous incident and not on his own intelligence and insight! Of course, the case which I shall cite is not to be compared with the great discoveries of Bernard, Richet and Pasteur, but it will illustrate equally well some of the conditions which prevail when chance plays a role in discovery.

About forty-three years ago, shortly after the x-rays were discovered, I was using the mysteriously penetrating light to look into animals in order to watch the little known processes of digestion. The churning and mixing of the food was clearly visible. Occasionally, however, my purposes were wholly checked because the motions came to a dead stop. That was a great annoyance; it seemed very strange, and I was at a loss to account for it. But in scientific investigations, as in daily living, obstacles may yield important values. I soon noticed that the cessation of the digestive activities was associated with signs of anxiety or other emotional disturbance. Could it be that I was seeing the harmful effects of worry on the organs which serve to make the food useful to the body? That proved to be true, for when I petted the animals reassuringly the churning waves promptly started again, and when excitement was induced the waves promptly stopped. There was an instance of serendipity—a discovery which I was "not in quest of," a disclosure which called for the application of "sagacity," to use Horace Walpole's expressions. It was the beginning of many years of research on the influence of fear and rage on bodily functions—research which ultimately led to insight into the agencies of our organism which maintain the stability of the extraordinarily unstable material of which we are composed and which give us freedom to live and carry on our various activities untrammeled by external heat or cold, by flight to high altitudes or by the internal changes produced by strenuous efforts in which we may engage. The observation of the effects of worry on digestion also resulted ultimately in a suggestive concept of the nature of emotional excitement, and, furthermore, in the demonstration of a chemical agent which acts as an intermediary between nerves and muscles when muscles are made to contract or relax.

There is another implication in Pasteur's dictum that chance favors the mind that is prepared; that is the importance of avoiding rigid adherence to fixed ideas. It is quite natural for the uninstructed intelligence to find a comfortable security and serenity in a set of conventional opinions which have been satisfactorily prearranged. The unusual is promptly dismissed because it is not wanted; it does not conform to the preconceived plan. The possibility of adventures in ideas is unknown to such benighted persons. We who live in a world which we recognize as not settled, stationary and finally immobilized, but as presenting all manner of possibilities of novel and unprecedented combinations and readjustments, must keep our minds open and recipient, ready for new views and fresh advances. We must not dismiss the unusual and the extraordinary aspects of experience as unworthy of attention; they may be the little beginnings of trails leading to great unexplored ranges of achievement. In a world organization which is in flux, in an anxious society groping its way possibly to new forms, shall we blind our eyes?

The great solutions may arrive unheralded, and unless we are prepared to weigh ideas on their merits and judge them fairly and critically we may not be participants in the momentous decisions, but, instead, worried and unhappy bystanders.

Regard for learning of the past, tolerance and free discussion of novel suggestions and readiness for cautious experimenting when opportunity offers—these features are typical of the prepared mind. They are typical, also, of the finest educational spirit. Indeed, it may be questioned whether a teacher who does not cherish an unprejudiced respect for the truth as handed down by our forebears and who is not on the alert for new revelations in the continuously opening vistas of truth—it may be questioned whether a teacher, lacking these fundamental attributes of intellectual integrity, is likely, himself, to develop minds which look out upon the world with perspicacity and adaptable understanding. A teacher is likely to create students in his own image. Alert and thoughtful graduates will go forth from a school or college when alert and thoughtful teachers, encouraged and fostered in their labors, exert their influence within its portals.

Here, I think, is a further implication of Pasteur's dictum that chance favors the prepared mind. That is that a school or college, by inspiring students with the high ideals of the best educational tradition, can make them ready to take advantage of the fortunate events which, amid extremely difficult and complex situations, are sure to appear. Not only in the physical and the biological sciences, from which I have drawn most of my illustrations, but to quite as great a degree in political, economic and social affairs, important and pressing problems call for solutions. A better world for all of us will be ours when these problems are solved. Many new discoveries are needed in order that these problems may be solved—discoveries of ways to achieve more perfect justice among men, a fairer distribution of the abundance which agriculture and industry can produce, assurance of conditions which will promote good health and effective medical care, freedom from the distress caused by great oscillations between financial booms and depressions, the reduction of crime and the number of criminals, the stabilization of family life, and the avoidance or rectification of numerous other social maladjustments. These are not hopeless situations. They can be largely remedied. The discoveries which will yield deeper insight into the modes of resolving these difficult and often baffling problems are likely to be made by minds which have been disciplined in directions which we have already considered. And when such minds confront the complexities involved in these extremely puzzling social and economic questions, they may be sure that quite unforeseen possibilities of securing answers will spring forth—chances of serendipity, for which they will be sagacious.

NATURALISTS IN THE WILDS OF BRITISH COLUMBIA

III. THE SUMMER AND PREPARATIONS FOR OUR SECOND WINTER

By JOHN F. AND THEODORA C. STANWELL-FLETCHER

DIMOCK, PENNSYLVANIA

FROM late May until the end of July, the open banks, meadows and woods were real flower gardens. One charming color combination succeeded another. Early in the season the open hillsides were red and yellow with columbines (*Aquilegia formosa*) and yellow daisies (*Arnica cordifolia* and *Arnica latifolia*) and white with saskatoon (*Amelanchier florida*). The dark floors of the spruce and pine forests were covered with carpets of white clintonia (*Clintonia uniflora*), bunchberry (*Cornus canadensis*) and beds of delicate pink twin flower (*Linnaea borealis var. americana*). Then there were waves of blue and purple *lupines* (*Lupinus* sp.) and Indian paint-brush (*Castilleja miniata* and *Castilleja angustifolia var. Bradburyi*) in every shade of red, pink and orange. The banks in front of our cabin were covered with wild roses (*Rosa acicularis*), the meadows and river banks with forget-me-nots (*Myosotis alpina*), blue-bells (*Mertensia paniculata*) and more masses of paint brush. In July the green meadows became a sea of acres of blue larkspur (*Delphinium Brownii*) *and monkshood* (*Aconitum columbianum*). With the fresh green of the newly leafed-out poplars and willows, the dark green of the evergreens and the mountains still white with snow, the world was a gorgeous place.

CHILCOTIN VARYING HARE

And in the midst of all this beauty came the mosquitoes; it was the last week of June. No one who has been in the far north in summer-time needs a description of the insect life. Although the flies and mosquitoes in the Driftwood River region were not nearly so bad as the ones we had experienced in the tundra and muskeg country, they made life miserable. It was impossible to work outside without head nets, and the roar of mosquitoes in swampy places or thick woods completely drowned out the song of birds in near-by bushes and trees. Our cabin windows and doors were well covered with wire screening, but the clouds of mosquitoes on the outside of the screens were so thick that swarms got into the cabin whenever a door was opened. By the end of July the worst of the mosquitoes was over. During August we had black-flies, but these were not nearly so bad as the mosquitoes. In late August and September there were also swarms of yellow-jackets which devoured every particle of meat that was not tightly covered. If we wanted a mammal skeleton cleaned for a museum speci-

men we had only to put it outside, and by nightfall it would be entirely free of meat and gristle.

The long days were very hot when the weather was clear. Our thermometer often reached 88° or 92° F. in the shade and went up to 120° in the sun. The nights were short and cool, the temperature dropping 30° to 50° or more as soon as the sun went down in the northwest. In May and June there were mornings when the water in our buckets had ice on it even when the temperature had been 90° in the daytime. It was not really dark until 12:00 at night and we could see to read at 10:00 P.M. At 2:00 A.M. it began to get light again. That country never did things by halves. It spoke in superlatives. The weather was never temperate and life was full of beautiful and miserable things, but in spite of many hardships the beauty always spoke to us most strongly.

WEASEL DRAWN FROM LIFE BY AUTHOR

The summer of 1938 was a very dry one—drier than any for some years, the Indians said. It was hard to believe that a country flooded with water from the tons of melting snow could become so dry. In July and August forest fires became prevalent. One especially bad one at the north end of Takla Lake began working up the Driftwood Valley. One day, clouds of smoke were so dense that we could not see fifty yards across the lake. Eyes smarted and breathing was difficult. We had no means of knowing whether the fire was four or forty miles away, but we did know that if it reached the dry pine ridges a few miles south of us there would be no hope of saving our cabin, so we promptly prepared to vacate. We made a log raft on which we could put our valuables and food, and had everything packed in duffle-bags and boxes ready to roll into the lake at a moment's notice. If the fire came, our only hope was out on the water, but even then, chances of surviving were small,

YOUNG COYOTE CAUGHT ALONG DRIFTWOOD RIVER. SEPTEMBER, 1938

for fires in that country were known to jump from one lake shore to the opposite shore a mile away, and our lake was only about five hundred yards wide. Hot, acrid smoke from a forest fire will suffocate a person quickly, and our lake was too cold to allow one to stay in its icy depths for more than a few moments. There was no sense in traveling north and leaving the cabin and our lake, for we might have been caught in the forests before reaching any large body of water. By nightfall there were still no signs of fire in our immediate neighborhood though the smoke was denser than ever. But in the early morning, at about 4:00 A.M., a light drizzle of rain began, later turning into a real rain after a few hours. The smoke gradually cleared away. We learned some weeks afterward that the fire was actually twenty-five miles from our lake. It took us nearly two days to move all our gear back into the cabin again and to straighten it out once more.

Early in August we bought a pack-dog from a white man at Takla. His name was "Wahoo" and he was a huge fellow weighing seventy-five to eighty pounds. Capable of carrying fifty pounds, he usually packed thirty-five pounds for us, and with Rex carrying fifteen to twenty-five pounds, longer trips were made possible. Wahoo had been chained up for months, and he greatly appreciated the freedom he had with us, as well as the companionship of Rex. Both dogs loved to work—as all dogs do; they went with us everywhere, and were a wonderful help, even though we were kept busy feeding them. Fresh meat would not keep at this season and we were obliged to fish hard for long hours nearly every day to keep ourselves and the dogs in meat.

During August we camped for a few weeks at the bottom end of Bear Lake. One night when two of Charlie's sons were camped near-by, we had a curious visitor. At bed-time we all heard a

A LARGE BUCK CARIBOU, OMINECA MOUNTAINS

strange cry from the woods, and a few hours later the dogs suddenly made a great racket. The Indians came over from their camp to tell us about a queer creature which they had distinguished dimly in the light of the dying fire embers. It was very large, they said, and "go soft just like a man on his hands and knees." When their trained hunting dogs had been let loose, they would not chase this animal in the usual eager manner, and the Indians, ever alert for the uncanny and supernatural, were scared. They built up their fire and remained awake the rest of the night. Judging by this description and the cry we had heard, we decided that it was a cougar (*Felis concolor*). Although cougars were frequently seen and killed in the Hazelton district and there were reports of one or two at Takla Lake, they had not reached the Bear Lake country and were unknown to the Indians there.

The next morning a black bear (*Euarctos americanus*) walked by along the edge of the lake, and when we reached home we found that apparently another bear had torn down a meat box from the rear wall of the cabin, removed the hinges with a light pat, and gone off with our last ham and four pounds of cheese. A black bear-cub skin, that had been tacked to the wall to dry, was found fifty yards away.

A week later, when one of us was going through the woods in search of warblers, he came upon a grizzly bear (*Ursus sp.*) eating berries. Man and bear were 100 feet apart and each saw the other at the same time. The bear went on feeding and ignored the intruder, who stood still and looked for a climbable tree, having no rifle other than a 410 bird gun. After a few moments the bear gave an irritated snort and moved off into the undergrowth.

This section of British Columbia was supposed to be great grizzly-bear country. The bears, both black and grizzly, were most often seen on the open moun-

tain sides at timber line or above, where they holed up for the winter. In late April or May they came out and, when the fish began to run in the lakes and rivers, came down to fish. In August and September they also gorged themselves on berries. Large numbers of poplars all around our cabin were covered with bear-claw marks and other signs. On our pack trip from Hazelton in August, 1937, there was such a strong scent of bears—like bad cabbage—in all the thickets, that we often had difficulty in persuading our horses to pass through. Everywhere we heard hair-raising tales of grizzlies attacking and mauling human beings, but in each case it turned out that the bears had been first interfered with by man, usually wounded, or their young placed in danger.

CAMP ON OMINECA MOUNTAINS. AUGUST, 1939

Late in August an unaccountable odor from the river caused us to make an investigation. We found the water choked with hundreds and thousands of scarlet spawning Kokanee (*Oncorhynchus nerka kennerlyi*). This dwarfed relative of the blueback salmon averaged eight inches in length, and apparently came up the Driftwood River from Takla Lake at the same time every year, according to reports from the Indians in that vicinity. The river teemed and reeked as the small fish made their way steadily upstream. Thousands of the dead and decaying Kokanee lined the gravel bars and banks, while countless numbers struggled feebly in the shallows. When the salmon first appeared, the river water was clear, and their red-gold bodies and bright green heads, glittering where the sunlight struck them, were an amazing sight. The trout gorged themselves on the small salmon and would not show interest in any other lure. Then the river was putrid with the dying fish as they lost their brilliant coloring and became scarred and ragged.

Tracks along the river banks indicated that almost all the animals in the country were enjoying a fish diet, and one day

we caught a young coyote (*Canis latrans incolatus*) pup alive. She did not appear to be vicious, and sat in the canoe between our legs as we paddled home. She had not yet cut all her teeth and was a beautiful little thing with huge prick ears and golden eyes that matched the tan and gray of her fur. We made a cage for her and fed her with milk and cooked fish, which she took readily from a spoon but never directly from the hand. After a few days, the weather cleared sufficiently for us to take a series of photographs. We held the little pup in our arms and fondled her and she only occasionally tried to bite. On the fourth day we let her go free. She went off a short distance and apparently spent the night half a mile away from the cabin.

When nature's scavengers had cleared the river banks of the dead Kokanee, and the river was its natural, clear self again, the trout were ravenous indeed. They were fat and full of fight; the mere suggestion of a spoon or spinner was immediately pounced upon and borne away into the depths below some rock or submerged log where the handling of a twelve-pound fighting trout was hazardous and fraught with difficulty. Previously, these same trout had been comparatively sluggish, but there was no doubt of their fighting capacity by September.

It was in September that we discovered in the stomachs of some of the trout three tawny lemmings (*Lemmus helvolus*). Two were in perfectly good condition, and one was partly digested. Later we found the remains of or saw the live animals in six different types of habitat in the Driftwood Valley: sphagnum bog, deep spruce and pine forest, the river bank, a rock pile, on the mountain sides and on the shores of Bear Lake. Judging from this and the fact that we had seen no signs of these lemmings before, we decided that there must be a sudden influx of them. The Indians reported that they had always found

PACK HORSES GRAZING ON MOUNTAIN MEADOW, AUGUST, 1939

them only on the sides or summits of mountains in previous years. With the help of our dogs, we caught four in our hands and discovered that they were capable of screaming loudly and shockingly. We also caught five of them in unbaited traps set in runways. At that time these lemmings were considered rare and much desired by the museum. They have since been reported as reaching plague proportions in two localities in British Columbia.

The gold of the poplars was like sunshine everywhere. And there was that silence which presaged the long winter ahead.

We made a trip to the top of the Driftwood Mountains, with the dogs carrying packs and thus permitting us to take enough food for some days. For a few miles we followed a wide trail, partly overgrown, which had been made by Indians to enable them to drag a large dug-out canoe, made from a balsam poplar (*Populus balsamifera*) at the foot of the mountain, to the Driftwood River. The first part of the actual climb was through a tangle of that miserable devil's-club (*Fatsia horrida*) which retarded progress considerably. For many hours it was necessary to cut our way through the prickly masses reaching above our heads. The first night we spent by the edge of a rushing mountain torrent in almost impenetrable forest growth. By noon the next day we reached a level open place, high up, where a stream trickled by a few sparse, stunted

BEAR LAKE INDIANS WITH SKINS OF BLACK BEAR CUBS. MAY, 1938

In early October, during one week, we took from the same trap set in a wide mouse runway in a sphagnum bog: one tawny lemming, one lemming mouse (*Synaptomys borealis dalli*), one British Columbia red-backed mouse (*Clethrionomys gapperi saturatus*), one meadow mouse (*Microtus pennsylvanicus drummondi*) and one Boreal white-footed mouse (*Peromyscus maniculatus borealis*).

Once again the fall coloring of the woods came to gladden our surroundings.

PACK HORSES ON HAZELTON-BABINE TRAIL. AUGUST, 1937

IN GROVE NEAR CABIN. POPLARS SHOWING BEAR MARKS.
NOVEMBER, 1937

MRS. FLETCHER WITH REX AND WAHOO IN FRONT OF CABIN.
DECEMBER, 1938

spruces. Here we strung up a light fly-tent and made camp. Behind and above us the mountain rose almost a thousand feet; before, and six thousand feet below us, was a grand view of the entire Driftwood Valley where our little lake gleamed in the sunlight in company with hundreds of others of whose existence we had been unaware. The mountains above our camp were precipitous on the east and steeply rolling to the west. There were miles of upland meadows, yellow where the burning mountain sun had scorched them, and green and full of autumn flowers in the hollows where there were springs or patches of old snow. From these beautiful uplands we had panoramic views of great mountain ranges and valleys from the south to the northwest. On the map this area was indicated by a blank space marked "Unsurveyed." These snow and glacier-covered mountains appeared to be higher, by thousands of feet, than any of the mountains we had seen previously in the country surrounding the Driftwood Valley and Bear Lake districts. Far below to the northwest we could see the spot where the Driftwood River began its winding journey to Takla Lake.

Off toward the south and to the northeast we saw two huge clouds reaching high into the heavens. They were pink below and blossomed out, as they rose higher, into lovely balls of purest white. But they were smoke clouds from huge forest fires, hundreds of miles away, where birds and mammals were suffering torture and death because of man's carelessness or greed.

While there was much evidence of recent animal life in the shape of deer, bear and goat tracks on the mountain tops, we saw and heard only two marmots (*Marmota caligata oxytona*), a few Townsend's solitaires (*Myadestes townsendi*), and some ptarmigan, probably the rock ptarmigan (*Lagopus rupestris*), which flew away over the jagged precipitous mountain side. The bears were

MR. FLETCHER WITH DOGS CARRYING PACKS. DECEMBER, 1938

obviously in the lowlands "berry picking" and most of the summer birds had departed.

When we reached home again we made preparations for the coming winter. The cabin walls were carefully rechinked with moss, for the old chinking was dry and shrunken and would let in cold winter air. Wahoo hauled a sled carrying earth which was piled around the outside walls of the cabin, and he helped us considerably with the woodpile, which was stacked higher and higher. This time we were well prepared for winter.

Our library was rather small and by the end of November, 1938, we had read everything at least three times over. Magazines were digested from cover to cover, including the advertisements. In this way we read much on subjects in which we were not especially interested, and decided that we obtained a much broader knowledge than we did from the wealth of reading material which one has barely time to skim through at home in the rush and hurry of the so-called civilized life. Our calendars were being marked off with alarming rapidity, and we reluctantly thought of our nearing departure in December from this land which was ever more delightful and interesting and which we had come to look upon as home. At night, when we stood outside our cabin to watch the low-hung stars, we had still that never-lost thrill of isolation and sense of aloneness. The light from the cabin windows was a feeble object in the vastness of the wilds around us. But in that cabin were contained all the things that made life possible.

In early November we made a brief trip to Bear Lake, where we met the pilot of the airplane which carried the trader's freight. Arrangements were made for him to pick us up on December 31st, or "as soon thereafter as weather permitted," from a lake thirteen miles from Tetana, as our lake was too small and the ice too unreliable for safe landing. He was to take us and the dogs down to

MR. FLETCHER WITH DOGS ON UNNAMED LAKE
NORTH OF LAKE TETANA. DECEMBER, 1938

LOOKING OVER DRIFTWOOD VALLEY. SEPTEMBER, 1938

Fort St. James on Stuart Lake, where we would start our first journey into the outside world.

On our return trip to Tetana it snowed considerably, and after that the temperatures were a little lower each day. The golden-eyes, three of them, were still with us, and our friendly dippers appeared once more, cheerily singing and chasing each other. Bear Lake Charlie came to us for treatment of a severe axe-cut in his leg, and we obtained three otter skulls (*Lutra canadensis evexa*) from one of Charlie's sons only after considerable persuasion. The boy would not sell these skulls and he wanted to be sure that no dire results would follow his parting with them. He was afraid that his mother would be possessed by the spirits of the three departed otters and eventually become insane.

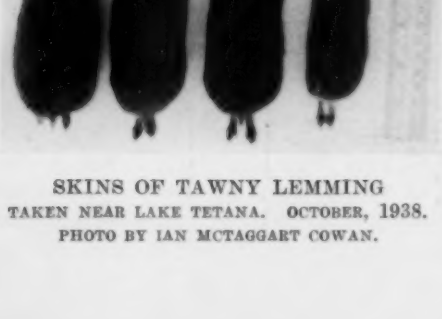
Snow came, and more snow. The "flour-sifter" was working in earnest. The animal tracks became scarce, and finally Christmas came once more. Just as during the early part of the previous winter, there were no signs of the wolves, and moose were scarce and we were unable to obtain any fresh meat. We lived on canned foods more than we liked. One of us reached the stage, by Christmas, where she was dreaming of "sausages bursting from their jackets." On Christmas Day we had a splurge of foods. For breakfast we ate oranges, bran-flakes, scrambled eggs (made from egg powder) and bacon, with toast and coffee. It was a bright day, 44° below zero Fahrenheit, and the dogs shook their feet and danced after a few minutes in the biting air. We read, played solitaire and parcheesi, and in the afternoon indulged in a delicious egg-nog, using the last two eggs which had been saved up for that express purpose. These were fresh eggs which were dipped in a preserving fluid and we occasionally got crates of them and kept them successfully for months. For supper we had tomato juice, clam chowder, corned beef and vegetables fol-

LOOKING DOWN ON DRIFTWOOD VALLEY. SEPTEMBER, 1938

MASKED SHREW
FOUND FROZEN IN LIFE-LIKE POSITION.
DECEMBER, 1937

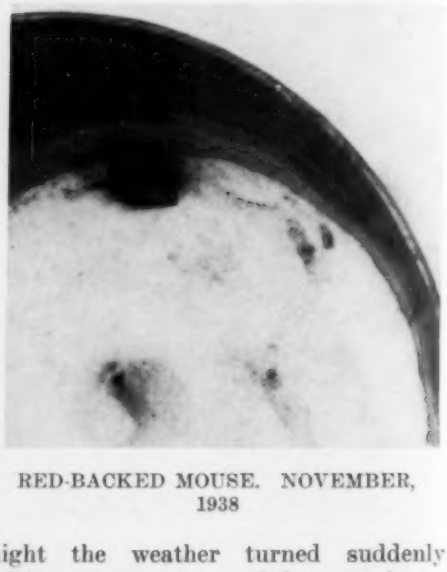
lowed by peaches and whipped evaporated cream; at eight o'clock we retired to bed.

Throughout the entire year and a half which we spent in the Lake Tetana region our health had been perfect. Never a sign of a cold or the usual germs that keep one half alive during most of the seasons in the civilized world. Our only bodily ailments were occasional mild cuts and muscular exhaustion. As far as we knew, the health of the Bear Lake Indians was also excellent unless they went out to the nearest post, where they got colds, flu, measles or whatever was prevalent. Our comprehensive supply of medical stores was practically untouched except for the few mild drugs we occasionally gave the Indians.



SKINS OF TAWNY LEMMING
TAKEN NEAR LAKE TETANA. OCTOBER, 1938.
PHOTO BY IAN MCTAGGART COWAN.

Before noon on December 29th, we said good-bye to our cabin and lake with much feeling, and promised them to return as soon as possible. In the afternoon we reached the lake where the plane was to pick us up. We were followed by the Indian boys who, with dogs and toboggan, were bringing the six to seven hundred pounds of duffle, specimens, etc., from the cabin. We made camp under the shelter of a huge spruce tree. On December 30th, the Indians went back to Bear Lake and we spent the day tramping a trail on the lake for the skis of the plane to land on. During the



RED-BACKED MOUSE. NOVEMBER, 1938

night the weather turned suddenly milder, snow came, and by morning a blizzard was sweeping over the land. With little success we tried to keep the double track on the lake packed down. The snow-storm lasted on and off for four days, during which time the temperature rose steadily and the weight of snow on the lake, coupled with the warm weather, caused "flooding" in places where water was seeping through cracks underneath the snow. Approximately four feet of snow fell during the storm, on top of the three feet already on the level ground. Dry firewood became more

and more difficult to find and carry; the trail on the lake had to be kept packed down and worst of all our reserve food supply was almost gone. But we were confident that the plane pilot, whom we knew to be a person of resource and wisdom, would find us at the first possible opportunity. Travel was almost impossible over the fresh damp snow into which we sank even on snow-shoes. It took two hours to make one trip up and down the mile-long track on the lake.

On the evening of January 3rd, the snow lessened and the moon appeared; it was almost full and we went out to the lake and packed the trail down for hours. The next morning was cold and clear and our trail was hardening. But we suspected that the plane if it came that day would stick in the slush below the snow. At noon, while we were resting from our exercises on the lake, we heard a droning, and soon the plane was circling about picking up our location, which we had marked with a huge cross of spruce branches. A few moments later we were hurrying along the trail where it had landed and stuck in the overflow. As we feared, our trail had not yet hardened sufficiently. The pilot greeted us with a grin and apologized for the storm which had held him back; then, with the co-pilot and the mechanic helping, we cut trees from the shores of the lake and jacked up the plane. When it was clear and taxied down to our pile of baggage, it stopped with a lurch and was stuck once more. This time was worse than before, and meant hours of labor before the plane could be freed. The afternoon was passing and so we were obliged to clear the broad skis and wait for the next morning. The men, on learning that we were down to our last can of beans and a few pilot biscuits, brought out their emergency rations. They had freshly-baked bread, meat and vegetables, and various kinds of canned foods which looked marvelous to us after several days of very scanty rations. They had ideas of heavenly dishes such as fried potatoes and onions. Unfortunately, we were obliged to demonstrate that when cooking outside under such conditions (the temperature was then 15° below zero Fahrenheit) over our huge fire, only the simplest canned things were practical. The pots of food had to be held over the fire which had sunk down several feet below our level and whose wet logs shot up clouds of smoke. Moreover, it was necessary for every one to dip out of the pots, for, if the food was put on plates and passed around, it froze hard before it was eaten. We wept in the smoke, blistered from heat in front and froze behind while we took turns at the pots and dried wet socks and moccasins. One of the men muttered that the next time his wife back in town complained of washing dishes he could tell her a thing or two.

BOREAL WHITE-FOOTED MOUSE

The airmen set up their small wireless set in a snowdrift close to the fire and worked patiently for hours with stiff and frozen fingers until they had managed to broadcast a message to headquarters saying they had found us O.K. and could not get back that night, but hoped to make it the next day. We in our turn were amused at the ways of the civilized world to which we were returning. We had been completely out of touch with the outside for months at a time with no one knowing whether we were alive or dead, and it had seemed quite unimportant.

Our dogs, utterly unused to people

other than ourselves and a few odd Indians, were astonished at the sudden coming of these strangers and the constant conversation and noise, as we sat by the fire below the spruce tree. After the airmen had burned a few holes in mittens, socks and moccasins from too sudden drying, they went to bed. Each had a warm sleeping robe, and after digging out a hole in the snow on the other side of the tree from us, using snow-shoes as shovels, they had gathered spruce branches on top of which they put a large grizzly-bear skin, one of our specimens, and the engine cover from the plane.

During the night the temperature dropped to 35° below zero Fahrenheit, and in the early morning we found that our trail on the lake was solid and smooth. The oil from the engine, which had been removed the previous evening, was heated and poured in the engine; two huge blow-lamps underneath the tarpaulin cover warmed the machinery, and our gear was loaded into the plane. After several hours, while the plane skis were chopped free from the ice into which they had frozen fast during the night, the engine roared and a few moments later we were climbing up over the lake, circling toward the south, and in a few minutes had passed over our little cabin at Tetana. It looked tiny, like a doll's house engulfed in a land of endless mountains and forests, but we had in our minds a very clear picture of it which would never cease to call us back, from the worries and hurries of the cities, to the fresh clear air and the wild-life of the woods.

TWENTY-FIVE YEARS' QUEST OF THE WHALE SHARK

ITS CONSUMMATION IN THE MOUNTED SPECIMEN IN THE AMERICAN MUSEUM OF NATURAL HISTORY

By Dr. E. W. GUDGER

HONORARY ASSOCIATE IN ICHTHYOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY

WHEN Alexander had brought under his sway the whole known world of his day, he is said to have fallen into a profound melancholy because there were no more worlds for him to conquer. Not so the scientist. As he climbs the mountain of knowledge his horizon expands and he realizes how much more there is to be learned. In this article is given in brief form some idea of long years of study of one fish, ending in the putting on exhibit of the most beautiful mount of it in the world. But, to the student it is clear that all investigators of the whale shark together have just scratched the surface. What exact knowledge do we have of its anatomy (of its curious gill-arch apparatus, for instance), of its food, of its habits and especially of its method of reproduction?

But let us take note of some things that have been learned since the fish was first described in 1828, and particularly of some of the things that the present writer has learned in his 25 years' pursuit of the whale shark. And then it may interest the reader to learn something of the various and long-drawn-out stages of painstaking work by which the crude skin of our whale shark has been transformed into the magnificent mounted fish now on display.

The whale shark (*Rhincodon typus*), portrayed in Fig. 1, is the largest shark that swims the seven seas to-day. It has been measured up to a full 45 feet and estimated up to 60 by a scientific man, and up to 70 feet by whale fishers accustomed to appraise the length of the leviathans of the deep. The whale shark, like the sperm whale, is especially large forward, having the biggest head and largest mouth of any living animal save some of the largest whales. In the mouth cavity of an average-sized specimen (say 30 feet long) an average-sized man can crouch, as Fig. 2 shows.

Another living shark, *Cetorhinus*, the basking shark, may attain to the length of *Rhincodon*, but it does not have the bulk. The basking shark is comparatively slender and has a small head ending in a pointed bullet-shaped snout with the normal-sized mouth underneath in the normal shark position. On the contrary, the enormous head of the whale shark continues forward and ends bluntly in the wide terminal mouth. However, both these huge sharks were far exceeded in size by the extinct shark, *Carcharodon*. We are ignorant of its form and outline, but since it left great triangular fossil teeth, 6 inches long, it is well named *megalodon*—huge-toothed. In length it probably reached 80 to 100 feet. This giant was the great-great-grandfather of the *Carcharodon* of to-day, the true man-eater.

All sharks, and particularly large ones, are, by the general public, automatically put down as man-eaters. And that is the first question asked by those who for the first time see the mounted whale shark. But for all its size, this giant of the seas is entirely harmless. Even when attacked by its one enemy—man—it offers no retaliatory violence, but merely seeks to escape by swimming or by diving. But

Photograph by courtesy of Mr. Charles T. Wilson

FIG. 1. WHALE SHARK ON BEACH. ACAPULCO, SOUTHWEST COAST OF MEXICO
THIS IS THE FISH WHOSE MOUNTED SKIN IS NOW ON DISPLAY IN THE HALL OF FISHES IN THE AMERICAN MUSEUM OF NATURAL HISTORY.

should a 30-foot specimen thresh out with its great tail-fin in 15-foot swings and strike a rowboat, it would surely reduce this to fragments. As a matter of fact a 30-foot whale shark is infinitely less vindictive and dangerous than a 30-inch vicious common dogfish.

Although at Acapulco, southwest coast of Mexico, whence our skin came, the whale shark is called "tigre del Mar"—the tiger of the sea—this is because its yellowish-white vertical stripes and spots resemble those of a tiger (Fig. 1), and *not* because of its disposition. The Cubans call it "pez dama," which may be translated as "checker-board fish" in allusion to the curious squares on its skin, each with a spot in it. But since the fish in Cuban waters is, as everywhere else, entirely harmless, the Cubans, with a better appreciation of its habits, give the words "pez dama" another significance—the "gentle fish." As a matter of fact *Rhineodon* is the mildest-mannered shark that swims the ocean.

Large sharks require much food, and, fossil or recent, they invariably have large teeth to cut or rend large prey. The exceptions to this rule are *Rhineodon*, the whale shark, and *Cetorhinus*, the basking shark. Both have very small teeth set in bands, and both feed on very small animals. In the whale shark, the backwardly hooked teeth are arranged in close-set rows to make a band reaching from corner to corner of the mouth. Such a tooth-band is represented in Fig. 3. The teeth of such a band number about 3,000 in each jaw, but each tooth is only about one eighth of an inch long, as Fig. 4 shows in natural size. If one were to put one's hand on the tooth band of *Rhineodon*, this would feel like a coarse file—hence the derivation of the fish's name, *Rhineodon*; Greek *rhine* = file, and *odous* (*odon*) = tooth; the file-toothed fish.

These small teeth indicate the kind of food on which *Rhineodon* feeds—small things, since it could not cut nor tear large objects. Not only is it a whale in size but in manner of feeding, for it must subsist on small fishes, squids, swimming crabs, jellyfishes and especially on the multitudinous very small things that float or swim at the surface of the water—things that the scientist calls plankton. To supply the energy to keep it—a huge engine—going, the whale shark must take

in vast amounts of these small objects. This it is believed to do by swimming along with its mammoth cave of a mouth open. Into this go food and water. The water passes through its curious sieve-like gill-strainers and out through the five gill-openings on each side of its head; the food is retained and swallowed.

The whale shark was discovered, dissected and briefly described 112 years ago (1828) by Dr. Andrew Smith, surgeon of the British troops at Cape Town, South Africa. In 1849, he published the full account of his findings, and among other things he says that "the inner extremity of each branchial canal is obstructed by a sieve-like apparatus . . . fringed with a delicate membrane offering an obstruction to the passage of anything but fluid." This description fell on my ears, deaf until four and one half years ago when I examined the gill-apparatus of the whale shark which was captured on the Long Island coast in August, 1935. Now it is clear to me that this gill-apparatus will catch everything but the most microscopic plants and animals. Also it is understandable why the whale shark has such a cavernous mouth-cavity. It must take in hogsheads of water to get the pints of the minute plants and animals on which it feeds. This plankton passes down a gullet having a caliber of about four inches.

Its great cave of a mouth to the contrary notwithstanding, the whale shark is not the fish that swallowed Jonah.

Early in June, 1912, I went by rail to Key West, Florida, on my way to study sharks and other fishes at the Marine Laboratory of the Carnegie Institution of Washington on Loggerhead Key, Dry Tortugas, the last far-flung outlier of the Great Florida Reef.

As my over-seas train sped across Knight's Key in the darkness, little did I know that here two days before there had been captured a giant sea animal concerning which it was written in the stars

After C. H. Townsend, 1913

FIG. 2. MOUTH OF A WHALE SHARK

THIRTY-EIGHT FEET LONG. IN THE CAVERNOUS MOUTH OF AN ADULT WHALE SHARK A GROWN MAN MAY CROUCH WITH ROOM TO SPARE.

that I had been "sentenced" to study it for the "balance of my natural life"—at any rate at this writing for over a quarter of a century.

The next mail, following that which came down to Tortugas with me, brought Miami papers. These were filled with adjectival descriptions of a great "sea monster" taken at Knight's Key two weeks before. Since some descriptions called it a whale and since all agreed on its great size and its white spots, I (having no more knowledge of the whale shark than a child) put it down as one of the smaller whales, called, because of its voracious habits, the killer whale, *Orca gladiator*. But I was presently to realize my error.

Late in the following July on my return north, I came by boat from Key West to Miami, through the Hawk Channel inside the Florida Reef, passing en route Knight's Key, henceforward to be remembered in whale shark annals. At Miami I hunted up Captain Charles Thompson, the harpooner of the "monster" and the possessor of the skin. He showed me this hanging over a long wooden support under a shed built to receive it on the bank of the Miami River.

This huge skin, 38 feet long and 18 feet wide (if spread out flat), was the most enormous sea thing that I had or have ever seen. That I was tremendously excited goes without saying. The skin had been cut and torn by harpoons and bullets and much maltreated by the skinners, but for all that, it was a wonderful thing to behold. The fact that the animal had a cartilaginous skeleton and open gill-slits showed it to be a shark, but its great size and the large pale white spots, which everywhere covered the skin save in the ventral region, led to the apparently unanswerable question—"What shark is this?" The question was worth answering. It *had* to be answered.

In the back of my head was a very strong recollection in a weak memory that somewhere I had seen the picture of a gigantic spotted shark living in the Indian Ocean. On the long journey to my home in western North Carolina, it finally came to me that this figure was in a book on zoology which I had studied in college many years before. At home, I found the book, "Elements of Zoology" by C. F. and J. B. Holder, and in it the picture. I then identified the great shark and wrote to Captain Thompson that it was *Rhineodon*, the whale shark.

Dr. C. H. Townsend (director of the New York Aquarium) had published some preliminary notes on this fish. I then wrote to Dr. Townsend that I had seen the skin and that I had a full account of its capture from Mr. Charles T. Brooks, of Cleveland, who had chartered Captain Thompson's boat and who was the real owner of the skin. Dr. Townsend then urged me to write up the capture in full, and suggested that as background for this I write the natural history of the fish to date. This was done and when the completed MS. was submitted to him, he generously offered to publish the paper in *Zoologica*, the scientific journal of the New York Zoological Society.

After B. A. Bean, 1905

FIG. 3. TOOTH BAND FROM THE UPPER JAW OF A RHINEODON 18 FEET LONG. THIS CAME FROM THE FIRST WHALE SHARK EVER RECORDED FROM THE WESTERN ATLANTIC OCEAN—ORMOND, FLORIDA, 1902.

The paper appeared in March, 1915. It was widely distributed (Dr. Townsend wrote me that the edition was 3,000 copies), and it surely put the whale shark "on the map." Incidentally and happily, it started me on a series of studies on this shark not yet entirely ended.

But this is not Dr. Townsend's only connection with my whale shark studies. Some years after I came to New York

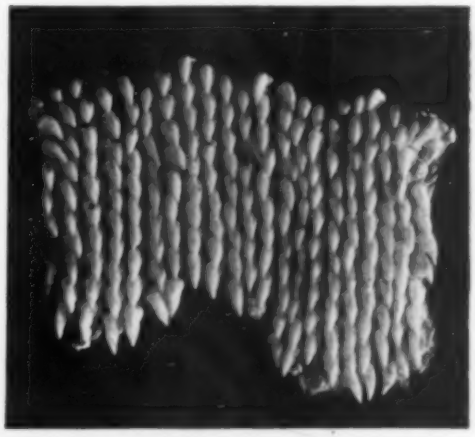
and when I was in the full swing of study and writing on the whale shark, Dr. Townsend found in the archives of the Aquarium and brought to me the original drawing made for the Holders' book. And incidentally it may be of interest to note that Dr. J. B. Holder had formerly resided at Fort Jefferson, Tortugas, and that at the time his book appeared (1884) he was curator of zoology in the American Museum. The drawing referred to has again disappeared, but the figure, because of its historical significance and because it led to my recognition of the whale shark and helped start me on its study, is reproduced from the book as Fig. 5 herein.

Since the capture of the Knight's Key whale shark in 1912, I have missed three other Florida specimens and the chances of getting a skin. In 1919, the first call came, but as editor of the "Bibliography of Fishes" I was chained to it and, working against time, I could not go, but it nearly broke my heart. In 1923, another fish was taken, but I was just out of the hospital and it would have been suicidal to go. In 1932, the word came—too late—the great fish had been cast away. But my turn and the fish and its skin were all to come to me later.

On Friday, August 9, 1935, came my great day—I saw a whale shark in the flesh. On that day, a 31.5-foot specimen blundered into a pound net off Fire Island Light on the south shore of Long Island, within 50 miles of New York's City Hall. It was brought in to Islip, Long Island, and I was called out to see and identify it. I went and saw, but all other sharks—even up to 12½ feet long—that I had ever seen and handled before were hardly more than minnows in comparison with this colossus. My excitement was great; I was unable to adjust my mind to realize how huge it was. I had no standard of comparison.

The story of the capture of this leviathan of the deep has been told elsewhere. Since the American Museum already had a skin, we made no effort to purchase the skin of the Fire Island fish. It was secured by Mr. W. K. Vanderbilt, has been mounted, and may now be seen in his private museum at Northport, Long Island.

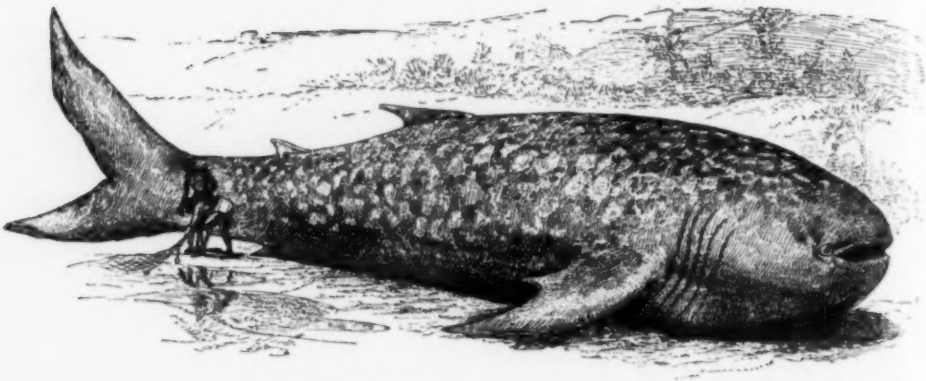
I have said that we already had a whale shark skin, and interestingly enough Dr. Townsend indirectly was instrumental in its coming to us. Two years earlier a picture of a *Rhincodon*, taken at Acapulco, southwest coast of Mexico, had been sent to him at the Aquarium, with the query "What is it?" He referred the letter and picture to me. The resulting correspondence led to our acquiring a skin from this region in April, 1935. And, at the time of the capture of the Fire Island fish, preparation of this skin for mounting had begun. The story of how this *Rhincodon* (Fig. 1) was captured at Acapulco, how the skin was sent to the museum, and how later Mr. Charles T. Wilson (head of the party that captured the fish) on learning of this, insisted on sending a check for the total cost of the skin delivered to the museum, has been told elsewhere. But it will be interesting to take up the story at the point where that account left off.



Photograph, American Museum of Natural History

FIG. 4. TEETH OF A WHALE SHARK

THIS IS A FRAGMENT OF A TOOTH BAND OF A RHINEODON TAKEN AT MARATHON, FLORIDA, 1923.



After C. F. and J. B. Holder, 1884

FIG. 5. A WHALE SHARK FROM THE INDIAN OCEAN.
THIS SHOWS THE RELATIVE SIZE OF A WHALE SHARK ABOUT 70 FEET LONG COMPARED WITH MEN OF NORMAL HEIGHT.

The skin was unpacked and scrubbed clean. Next it was stretched out flat and photographed to show the relative position of the various fins and particularly of the spots and bars (Fig. 6). Then it was "fleshed"—*i.e.*, all the pieces of flesh adherent to the inner side were scraped off. Finally the skin was placed in a vat of tan-bark extract, where it remained for 8 months until it was thoroughly tanned. Thus prepared, it will last almost forever.

The task of mounting the 18-foot skin was turned over to one of our skilled men in the department of preparation. First he constructed a rough manikin of wood and chicken wire to hold his modelling clay. Then, beginning in November, 1935, on this rough manikin he modeled in clay the body of the shark, "trying on" the skin scores of times, and patiently sculpturing this clay model until it and the skin fitted each other fairly well. During this time his work was constantly studied and criticized by the writer and the other members of the department of fishes. When all adjustments had been made to the satisfaction of every one, a plaster mold—divided into two halves right and left—was made of this model. Next in each half mold there was built a half-manikin out of burlap, papier-maché and chicken wire. This was braced on the inside by a wooden framework. The two halves of the model were then united, the seams covered with burlap and papier-maché and the whole shellacked. Thus was created an imperishable base on which to place the skin.

The manikin was next set up on a stand, and then with papier-maché and plaster this was painstakingly modeled into the final form. Along with this went innumerable fittings of the skin. Thus the manikin was sculptured to its final perfected form. And now there confronted the preparator a new problem which had to be solved before the final adjustment of the skin was made. The fibers in a shark's skin seem to run in almost all directions. This makes shark leather the strongest in the world, but it certainly added to the preparator's perplexities, for our tanned shark hide was covered everywhere with a multitude of puckerings and wrinkles. These by patient stretchings and rubbings were finally got out of the skin—and, at long last, the final stage, that of restoring the normal color to the skin, confronted us.

In the process of tanning and of the long-continued manipulation of the wet skin in fitting it and the clay model to each other, the original color had faded out and the spots and vertical bars had disappeared. Now was realized the sound

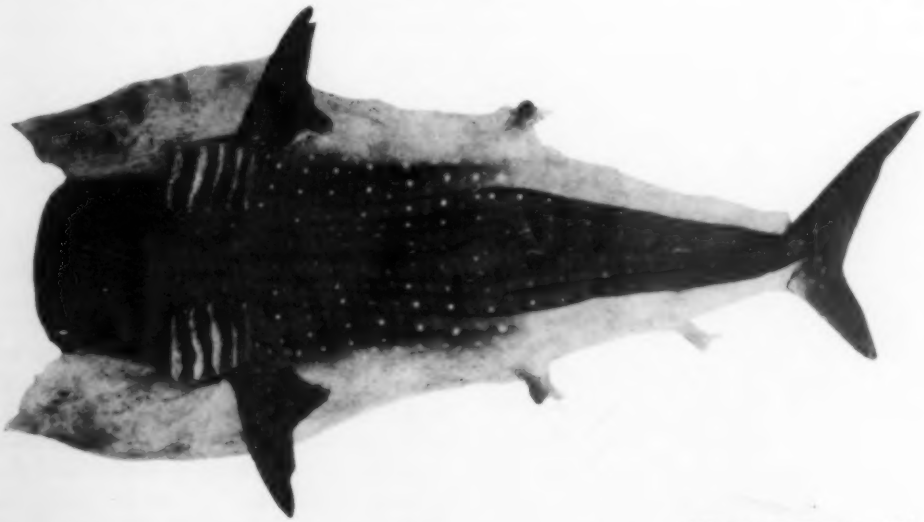
judgment shown in having a photograph made of this skin (Fig. 6). This gave us the relative position and sizes of spots and bars. But what was the normal ground color of the fish and what the shade of spots and bars? I had seen the Fire Island fish, but not until at least 8 hours after it had been captured. The colors then, after exposure to sun, air and drying, were not the normal life colors. Furthermore, I had been too excited at that time to note accurately the coloration of that fish.

Resort was next had to the published descriptions. But practically all these had been made from fish dead for hours. The best judgment of everybody was then concentrated on the problem, and sample experimental colorings were made on heavy drawing paper draped over the fish—and no one was satisfied. But just here good fortune came to our help. Dr. William Beebe, Mr. John Tee-Van and Miss Jocelyn Crane had a short time previously returned from an expedition of the New York Zoological Society to the waters around Cape San Lucas at the tip of the peninsula of Lower California. Here they had seen dozens of whale sharks, had glided alongside of them day by day. These observers were called in as referees and gave us first-hand information of the color of the *living* swimming fish. With their help the final putting on of color was done and the fish coated with a dull-finish varnish to protect the skin from air and dust.

It may interest the reader who cares about such matters, to get some idea of the time it took our skilled preparator to transmute the skin shown in Fig. 6 into the magnificent mount shown in Fig. 7. This, it will be seen, is somewhat proportionate to the time it took me to get a whale shark skin for him to work on.

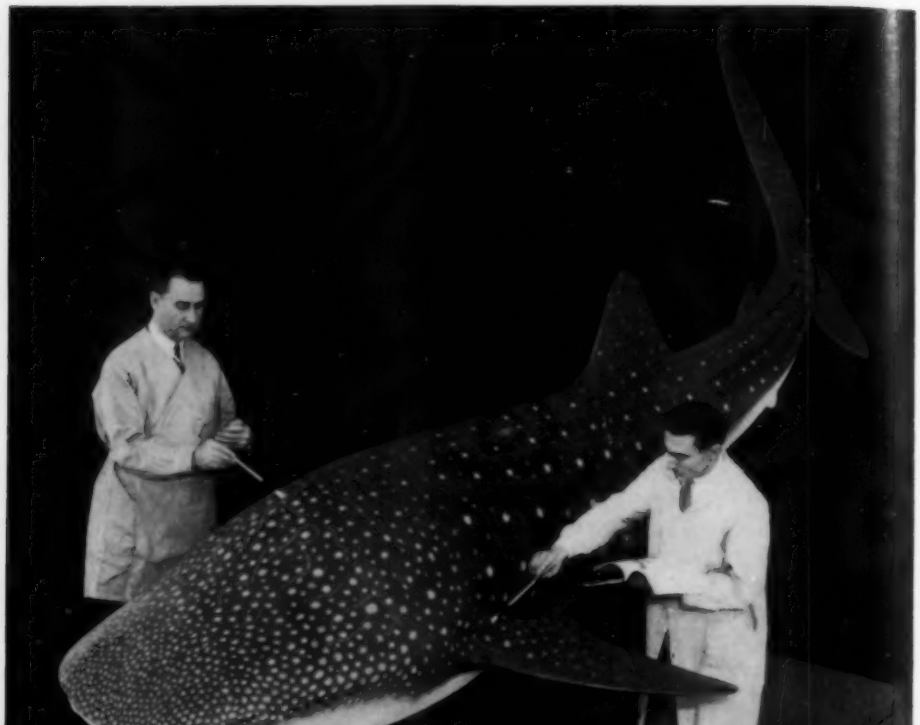
This task, from start to finish, called for an infinitude of careful, slow, minute study and work, which began in November, 1935, and ended in November, 1936—practically a year of hard work. What was the cost in dollars and cents I will not set down. Suffice it to say that the expenditure in money may be judged by the expenditure in time. Such work can not be hurried nor skimped if one wishes a real "job."

And now for comparison let us have a brief census of other mounted whale



After E. W. Gudger, 1935

FIG. 6. SKIN OF THE ACAPULCO WHALE SHARK.
THIS SKIN, MOUNTED AND WITH SPOTS AND BARS RESTORED, IS SHOWN IN FIG. 7.



Photograph by Thane Bierwert, American Museum of Natural History

FIG. 7. THE MOUNTED SKIN OF THE WHALE SHARK IN THE AMERICAN MUSEUM. DR. JAMES L. CLARK, DIRECTOR OF THE DEPARTMENT OF PREPARATION, AND MR. LUDWIG FERRAGLIO, WHO MOUNTED THE SKIN, ARE RESTORING THE MARKINGS OBLITERATED WHEN THE SKIN WAS TANNED.

sharks as a background for this completed product.

There are six mounted whale shark skins in the world's museums to-day. In the Muséum d'Histoire Naturelle at Paris is the mounted skin (1860) of the specimen (the first ever described) taken in Table Bay, in 1828. In the British Museum is a Ceylonese skin mounted in 1890. The Colombo, Ceylon, Museum has a skin mounted in 1889. Another (dated 1894) is in the nearby Madras Museum. In the Philippines (prolific home of *Rhineodon*) a mounted skin in the University of San Tomas has gone to pieces. And so have commercially mounted and displayed skins in Japan (1901), Miami, Florida (1913), and Cuba (1930). It should be noted that none of these skins was tanned.

All the museum mounts above listed are from 70 to 42 years old. There are, besides our fish in the American Museum, two modernly mounted specimens. A skin collected at Acapulco in 1931 was mounted under the direction of Dr. Einar Lönnberg (1933) and is on display in the Riksmuseum at Upsala, Sweden. Then, as noted, the skin of the Fire Island fish is mounted and is in Mr. W. K. Vanderbilt's museum at Northport, L. I. This skin was not tanned—I can not say about the Upsala one. Both skins are far better mounted than any of the old skins, but both fish are shown straight and lack the grace and beauty of our specimen.

There are three painted casts or models to be noted. A cast of 13 feet 7 inches was at last report in the Trevandrum Museum at Trevancore, India. Then there is our six-foot plaster model of the specimen taken at Marathon in the Florida Keys in 1923. This has been presented to the College of the City of New York in memory of Dr. Bashford Dean. And lastly there is a 35-foot model recently completed in the British Museum under the watchful eye of Mr. J. R. Norman.

The great day came at last—December 4, 1936. The mounted fish was done to the last minute detail. Mr. Charles T. Wilson, who generously gave us the skin and paid for its mounting, came up to see what we had done with his gift. With him came the Mexican Consul General and other Mexican friends from Acapulco where the fish was captured. We received them in the hall in the Roosevelt Memorial Building in which the great fish was temporarily installed. The coverings were removed, and this magnificent mount shone forth in all its beauty. That these terms are not exaggerated, let the reader judge by reference to Fig. 7 showing the great shark in "head-on"-lateral view.

By referring to the sizes of whale sharks mentioned in the first section of this article, it will be seen that our mounted fish is a young and small specimen. It measures 17 feet 10 inches over curves, but, mounted curved as it is, 14 feet 5 inches between perpendiculars. The mouth is 2 feet 10 inches wide, the width over curve of head between eyes is 3 feet 6 inches, the girth just in front of the pectoral fins is 9 feet 3 inches, and the spread of these fins 7 feet 2 inches. The spread of the caudal fin is 7 feet, 6 inches—18 inches greater than the height of a tall man. Yet small as is this whale shark, it is far larger than the largest mounted fish in our Hall of Fishes—so large that we have been troubled to find a place in which it can be adequately displayed.

This then was the consummation of my 25 years' work on the whale shark. By correspondence I have pursued this great fish around the world in its three central oceans and in their dependencies. By a study of the literature and by this far-flung correspondence, data have been obtained which have enabled me to make about 25 faunal records of the occurrence of *Rhincodon* in regions where it was previously unreported, or to record additional specimens in regions where it had been previously known.

One would think that, because of its great size and eye-compelling coloration (the most extraordinary found on any shark), this fish would be well known and many times reported. But in spite of a fine-combing of the literature since 1828, I have been able, as of December 31, 1935,[1] to find records of but 76 whale sharks captured or seen since its discovery in Table Bay, South Africa, in 1828—107 years before. The voluminous data thus amassed, I have synthesized into an extensive article on "The Geographical Distribution of the Whale Shark" published in the *Proceedings of the Zoological Society of London*, January, 1935. To this the interested reader is referred.

Along with the collecting of all these data has gone the amassing of the greatest collection of whale shark photographs in the world. There are almost a score of these. In fact, I have copies of every whale shark photograph save one, of which I have ever been able to get word. But none of these, nor all of them, gives me the thrill that I experience when I gaze upon our mounted fish—the end product of a 25 years' quest.

[1] Since this date, accounts (mostly very recent) have come to hand of about 25 additional specimens. Some of these accounts await publication.

SOME GEOGRAPHIC ASPECTS OF THE MANUFACTURE OF MEZCAL

By Dr. RAYMOND E. CRIST

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A TRIP to Mexico is a journey to a world entirely different from our own. Not only is the traveler transported to a region inhabited by people of another race, but he suddenly finds himself in another time in the history of the world; and that time is comparable in many respects to the late Middle Ages, when the guilds flourished. In the Mexico of to-day household activity is very great; master craftsmen of both sexes make rugs, pottery, sandals, mats, baskets, embroidered goods, etc., and these goods are transported on foot long distances from the place of manufacture to the market.

In those parts of Mexico where the maguey (agave) plant thrives either the pulque or mezcal industry is well developed—the former particularly in the more densely populated regions. Pulque is the fermented juice of the maguey, whereas mezcal, the distilled liquor from the same plant, is made in primitive establishments in many parts of the country. There are a few modern factories, to be sure, but for the most part mezcal is produced in small establishments which are outgrowths of household industries.

The long broad leaves of the maguey plant (Fig. 1) contain longitudinal fibers, known as sisal. In Yucatan there are great plantations of agave plants from which is produced on a large scale the sisal or henequen of commerce, most of which goes to the United States. Here it is familiar to us in the form of small ropes or binder twine. However, on the Central Plateau of Mexico and in the various dry valleys, most of the sisal is used locally to make ropes, mats, sandals, bags, etc. But the stocks which remain after the leaves are cut away are not wasted. They are carefully transported to the mezcal factory. Here they are slowly roasted in the open courtyard on a pile of heated stones (Fig. 2). Once roasted the stocks are crushed under a huge stone roller, which is pulled around

FIG. 1. MAGUEY PLANTS
FROM WHICH MEZCAL IS DISTILLED.

FIG. 2. PILE OF STONES
WHICH ARE HEATED AND ON WHICH THE MAGUEY STOCKS ARE ROASTED.

FIG. 3. HUGE STONE ROLLER FOR CRUSHING ROASTED MAGUEY STOCKS.

and around by a patient ox or mule (Fig. 3). Thus the thick stocks are reduced to a pulp, and then the entire mass is placed in large wooden vats and left to ferment. After fermentation has taken place about fifteen gallons of the mixture of brownish liquid and fibrous pulp—which smells much like ensilage—are placed in a big copper still and boiled. One hour's boiling yields from three to six liters of mezcal, which is condensed in a worm which runs through a barrel

FIG. 4. EMPTYING AND FLUSHING THE COPPER KETTLE USED AS A STILL.

FIG. 5. FIBROUS MATERIAL AFTER BEING RUN THROUGH THE STILL.

of cold water. Then the kettle is emptied (Fig. 4). The juice is dipped off and thrown in the yard; the fibrous pulp is carried out to a huge pile away from the building, where it is allowed to rot (Fig. 5). When the kettle has been emptied, it is thoroughly flushed out with fresh water, and then another batch is added and the process is repeated.

Even to the casual observer it is apparent that one of the big problems of the drier areas in Mexico is that of obtaining firewood. A mezcal factory which was visited in 1938 was confronted with this same problem. All sorts of material were used for firewood: dried maguey leaves, gnarled stumps of small shrubs, reeds, etc.

It is not always feasible to visit a mezcal factory. The product is subject to a government tax. However, in order to avoid paying the tax, work at the factory is often carried on without the knowledge of the local inspector. At such times the owner is very wary of letting any one visit the premises unless he knows him well.

The mezcal industry is a kind of overgrown household industry—there was even a little shrine in one corner of the building. But such household industries are legion in Mexico and have made possible a kind of local or regional self-sufficiency—at a rather low standard of living, to be sure. The introduction of a modern system of transportation is in the process of breaking up this local self-sufficiency, but it is to be hoped that the process will be so gradual that the present economy will not be completely disrupted before it can be supplanted by the economic set-up of the future—one that is intra- as well as inter-national. Otherwise thousands of artisans who now have a feeling that they "belong" will no longer be able to dispose of the products of their hands, yet will not be able to fit into the new system. They will thus join the urban unemployed and increase social unrest. May the industrial and political leaders of Mexico keep their eyes on the past as well as on the future as they formulate current policies for their nation.

EXPLORING THE CHEMICAL CAUSES OF CANCER

By Dr. GRAY H. TWOMBLY

MEMORIAL HOSPITAL FOR CANCER AND ALLIED DISEASES, NEW YORK

Our scene—a cold winter's day, the middle of January, 1756. The place, the great city of London, a vast multitude of small houses topped by innumerable chimney pots. The good people of the city are keeping themselves warm by much Scotch wool on their backs, or by alternately toasting themselves front and back at open grates in which burn chunks of soft coal. The smoke adds to the gray fog and piles up its black distillate of soot in the flues.

Down the street in Southwark comes riding a rather elegant little man in a plum-colored coat. Suddenly—a shout; a bustle in the narrow street; the horse rears and bolts and the little man lies in the gutter with his ankle twisted and deformed, the bone protruding through the skin on the inner side. A crowd gathers and some offer to help him up, while others go for a coach.

But—what sort of man is this? He looks at his own ankle, refuses the proffered help, calls after those who would get him a coach to stop, and insists on lying quite still on the cold pavement, while a man goes all the way to Westminster, some two or three miles away, to summon the two nearest sedan-chair carriers to come with their poles. When they return they find he has bargained with one of the neighbors and has bought a door. This is taken from its hinges and the poles nailed to its edges. The door is laid alongside the man who is placed on it without disturbing the injured foot, and so he is carried through Southwark over London Bridge to his own fine house near Saint Paul's.

By his amazing presence of mind and cold-blooded self-control this man has saved the protruding bone and the injured tissue from contamination with the dirt of the street or of the interior of a jostling public coach. No tetanus spores have found their way to the wound. And at the advice of his old preceptor, Mr. Nourse, the leg is not amputated but heals by first intention.

The injured man was Mr. Percival Pott, surgeon at Saint Bartholomew's Hospital. He was 43 years old and, although he had been one of the chief surgeons at the famous old institution for seven years, he had written only one brief case report up to this time. As a result of his broken leg and his enforced idleness, he began a treatise on hernia, and so commenced a series of surgical writings which included dissertations on injuries of the head, fractures, cataract, lacrimal cyst, the cure of hydrocele, tumors of the testicle, tuberculosis of the spine, hernia and stone in the bladder, fistula in ano, polyps of the nose and so forth. The kind of fracture of the ankle which he sustained in his fall from his horse is known to this day as Pott's fracture. His description of tuberculosis of the spine with its abscess formation, destruction of the bone and spinal deformity and paralysis, is a medical classic and has united his name eternally to that malady, Pott's disease of the spine.

His writings have a modern ring which is truly surprising when one considers the time in which he lived—before the microscope, before asepsis, before anesthesia—when the learned still talked of the humors and routinely bled and purged their patients to their detriment. He himself belonged to the Company of

PERCIVAL POTT, ESQ.
ENGRAVED BY HEATH FROM A PICTURE OF SIR JOSHUA REYNOLDS.

Barber Surgeons, disbanded in 1845. In a preface to one of his works he says,

> Diseases have, it is true, in general, a sort of regularity and order, a series of causes and events, by which they are known and distinguished; yet we do now and then meet with such odd irregularities, such strange and unusual consequences, as puzzle and alarm even the soundest judgment, and the longest experience; and unless these be noted, the history of distempers will be imperfect.
>
> From writers of systems and institutes (of surgery at least), such kind of knowledge is not to be expected. They are most frequently mere compilers, and do little more than copy each other. The information which they convey is at best but superficial, and more calculated to enable men to talk, than either to judge or to act. It must be from a careful attention to the cases of individuals, and from an observation of diseases, in their irregular and infrequent forms, as well as their more customary ones, that true and extensive judgment can be acquired.

In the next paragraph he says that careful recording of the phenomena of disease "might perhaps lessen our faith in general doctrines and theories, but would render us more attentive to facts, and thereby furnish us with a much more useful kind of knowledge."

Percival Pott died in 1788, at the age of 75, of pneumonia which he probably caught because he insisted on making a round of calls on his patients on a winter's day when he was already sick with a cold. He served Saint Bartholomew's Hospital "man and boy," as he used to say, for over 50 years.

KATSUSABURO YAMAGIWA.

In 1775 this careful observer wrote a description of a "disease peculiar to a certain set of people, which," as he says, "has not, at least to my knowledge, been publicly noticed; I mean chimney-sweeper's cancer.

It is a disease which always makes its first attack on, and its first appearance in, the inferior part of the scrotum, where it produces a superficial, painful, ragged, ill-looking sore, with hard and rising edges; the trade call it soot-wart. I never saw it under the age of puberty, which is, I suppose, one reason why it is generally taken, both by patient and surgeon, for venereal; and being treated with mercurials, is thereby soon and much exasperated. . . .

The fate of these people seems singularly hard; in their early infancy, they are most frequently treated with great brutality, and almost starved with cold and hunger; they are thrust up narrow, and sometimes hot chimneys, where they are bruised, burned, and almost suffocated; and when they get to puberty, become peculiarly liable to a most noisome, painful, and fatal disease. . . .

The disease, in these people, seems to derive its origin from a lodgement of soot in the rugae of the scrotum. . . .

RICHARD VON VOLKMANN
AS SURGEON-IN-CHIEF IN THE GERMAN ARMY DURING THE WAR OF 1870–1871.

This observation of Pott's forms the basis for our present knowledge of the possibility of producing cancer with pure chemicals and this in turn bids fair to provide the key, or one of the keys, with which we may unlock, perhaps, the secret of cancer formation, prevention and cure, in the future. The story is a fascinating one and apparently is only in its early chapters. It would certainly enthrall Pott, for it is a story of observation and not of theory.

Pott's discovery was one which could have been made easily only in England where, as was mentioned to start with, the common form of heating for homes is soft lignite coal burned in an open grate. Chimney-sweep's cancer does not occur or, at least, occurs with the utmost rarity in America. At the Memorial Hospital in New York, where more than 3,000 new cases of cancer are seen every year, the only cases related to this disease are not true chimney-sweep's cancer at all but have occurred in workers in oil refineries, gas works, coke plants, etc., and even then there are only nine cases on file. Pott's observation was passed on by "writers of systems and institutes of surgery who do little more than copy each other," as he says, for a hundred years.

Had one journeyed to the City of Halle in Saxony in 1875 and gone to the University Surgical Clinic, one would have seen, without doubt, a man of medium height but with a commanding personality who sported a most impressive set of Dundreary whiskers and who was soon to become, through his extensive surgical observations and writings, one of the most prominent surgeons of Europe. His name was Richard von Volkmann and he was the chief of the surgical clinic and one of the first men to successfully use the antiseptic method in Germany. His writings included not only contributions to orthopedic surgery, the description of an improved method of removing the rectum for cancer, how to operate on cysts of the liver and operations for tuberculous joints, but a delightful book of fairy stories which he first wrote as letters to his children when he was waiting wearily with the German Army outside the gates of Paris for its surrender in the wintery siege of 1870-1871. This man was also a keen observer like Pott and wrote of what he saw rather than what people had said in the past. He described three cases of cancer of the scrotum occurring in men engaged in the manufacture of paraffin from lignite. He went into great detail over the chronic dermatitis which these workers

showed after a short time in the factory. Although the irritation of the skin was widespread, the tumors appeared usually, strange to say, on the scrotum only. Volkmann called attention to the similarity of this affliction with the cases described by Pott. His observations suggested the presence of a chemical or chemicals in coal-tar as a cause of cancer rather than the mere irritation from dirt and grime which might have accounted for the cases in chimney-sweeps.

Our tale having started in England, then gone to Germany, now jumps to Japan where, at the beginning of the twentieth century, the bright young men were looking with admiring eyes at the culture of the West and many were coming for study with the great scientific leaders in Germany. One of these was a man called Katsusaburo Yamagiwa. He was born in 1863 and studied medicine at the Tokyo Imperial University, where he graduated in 1888. In 1891, when at the age of 28, he had just become assistant professor of pathology, the Japanese Government sent him to Germany to study under the great Robert Koch, the discoverer of the tubercle bacillus. However, when he arrived, he found there a man he disliked and disagreed with, Dr. Kitasato. This led him to desert Dr. Koch and work instead under the direction of the great Rudolph Virchow, the "father of pathology"; and so was laid the way for the discovery which has made the name Yamagiwa known and remembered all the world around. Virchow believed cancer to be due to chronic irritation. Following out the idea of his teacher, Yamagiwa, as professor of pathology in Tokyo in 1913, set one of his graduate students, Ichikawa, to the problem of trying to produce cancer, first with scarlet red and then with tar. How odd the ways of Dame Fortune! In 1899 Hanau had painted animals with tar for long periods of time without producing cancer but he had used rats and the skin of the rat, as we know now, is very resistant to cancer production by tar, though the reason is still obscure. Cazin in 1894 had done the same with the dog. Haga in 1913 used the right animal but did not have patience to continue the treatment long enough; and so it was left for these two undiscourageable Japanese to make the great discovery that long-continued painting of the ears of rabbits with tar would ultimately result in cancer, and this fact they published in 1915. For the first time it was possible to produce cancer of the skin at will with a chemical agent. It was shown soon after that mice were even more susceptible than rabbits.

Yamagiwa was a simple man, whose only diversion outside his laboratory was writing poetry. He was afflicted most of his life with tuberculosis. He was always poor in money but rich in the love and respect of his students, so that when he retired from active teaching they banded together and bought him a house, the only one he had ever owned. He died in 1930.

An austere, intellectual, successful English surgeon, a German Geheimrat who wrote children's fairy tales, and an impecunious, patient, conscientious Japanese who wrote poetry—they pass before us a strangely assorted trio, but all three united by their thirst for truth and their unswerving reliance on observation rather than theory.

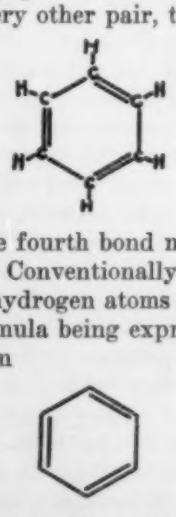
Our interest turns now from the individualities of the investigators to the fascinating development of the problem itself, partly because we are too near the subsequent discoveries to see the men who made them in their right perspective and partly because the number of men concerned is too great. These discoveries form an intriguing tale in themselves, a tale hardly begun and rich with future possibilities.

The greatest strides next to be made were the products of a group of workers led originally by Archibald Leitch at the

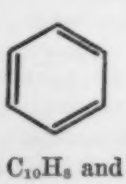
Royal Cancer Hospital and now by Ernest L. Kennaway since Leitch's death in 1931. Their goal was the discovery of which one of the multitude of chemical compounds in coal-tar was responsible for cancer formation. Kennaway made an important step in this direction when he found, in 1925, that acetylene, HC≡CH, heated to 700° C. yields a cancer-producing tar. This material obviously must be made up of carbon and hydrogen—that is, must be a hydrocarbon, thus eliminating the other elements and suggesting that the active material is composed of benzene rings hitched together in some fashion.

Leitch and Kennaway had collected many different types of cancer-producing agents, some made by distillation at varying temperatures from various types of coal-tar and paraffin oils, and even from human skin and muscle, and others synthesized from acetylene and isoprene. W. V. Mayneord, the physicist at the same institution, pointed out that many showed a characteristic fluorescent spectrum with bands at 4,000, 4,180, and 4,400 Angstrom units and this was further elaborated by Dr. Izrael Hieger, who examined 750 such substances with his spectroscope. The use of the spectroscope in the search was truly a long jump along the road of discovery. The supposition that these bands were related to cancer production was a large one but to the person who thinks of the magnitude of the problem the laboratory had set for itself, to pick out of the million possibilities the one chemical combination in coal-tar able to cause cancer, the proof that this guess was correct tells of the saving of years of work. Hieger noticed that 1:2 benzanthracene showed the same bands as the known cancer-producing agents, though itself inactive, except that their absolute position in the wave-length scale did not correspond exactly. He drew the conclusion that increasing the mass of the benzanthracene molecule might shift the bands in the right direction. A method of making 1:2:5:6 dibenzanthracene had just been published by a German chemist, E. Clar, entirely apart from any thought of cancer research. On Hieger's assumption Dr. J. W. Cook synthesized this material and it was tested in mice and shown to be strongly cancer-producing when applied in a solution of benzene. Tumors so produced were exhibited at the meeting of the British Medical Association in July, 1931, by Dr. Cook. Burrows, Hieger, and Kennaway injected the same substance, dissolved in lard, subcutaneously into rats and mice, hoping that it might produce cancer of the bladder. They found that it failed to do what they had hoped but it did produce sarcomas, cancers of connective tissue, in 31 out of 93 mice, and in 15 of 67 rats. These observations were published in January, 1932.

What do we mean when we speak of 1:2:5:6 dibenzanthracene? As all who have studied organic chemistry remember, benzene is C_6H_6 and the structure is thought to be a hexagonal arrangement of the carbon atoms, each attached to two others and to one hydrogen atom, the fourth valence bond of the carbon atom being represented as a double bond between every other pair, thus

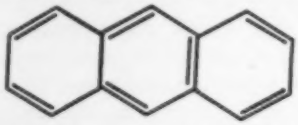


Actually the fourth bond may be across the ring. Conventionally the carbon atoms and hydrogen atoms are not written, the formula being expressed merely by a hexagon

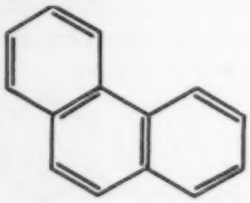


Naphthalene is $C_{10}H_8$ and is written

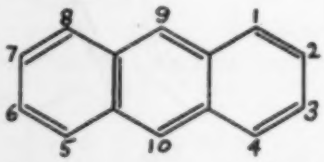
Anthracene is $C_{14}H_{10}$ and is written



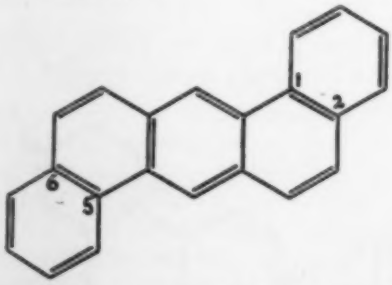
The benzene rings in this case are in a straight line. If they are not in a straight line, one has the compound called phenanthrene



To simplify the nomenclature, the positions of the carbon atoms in anthracene are numbered thus

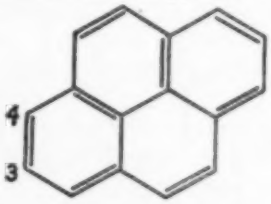


It is easy to see what 1:2:5:6 dibenzanthracene must be, the name obviously meaning that two additional benzene rings are added to anthracene in the 1:2 and 5:6 positions

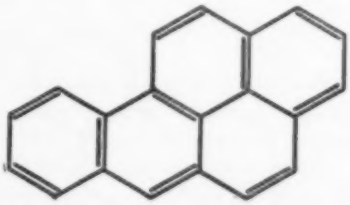


It was this compound which was first shown by the London group to be a pure hydrocarbon having, to a fairly high degree, the ability to produce cancer. Strange to say, this substance does not occur in coal-tar and is not the substance causing cancer in chimney-sweeps or tar-workers so far as we know. It was discovered by reasoning from what was known about cancer-producing fractions in coal-tar rather than by extraction from these fractions.

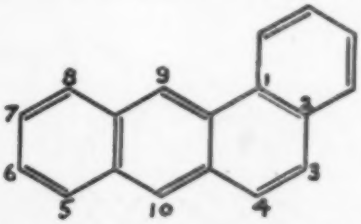
It was only a year before Cook, Hewett and Hieger had found another related substance, this one very much more potent in cancer-producing power and occurring in the cancer-producing fractions of coal-tar. Hieger isolated 50 grams of it from two tons of gas works pitch. It is known as 3:4 benzpyrene and is considered to be pyrene



with a benzene ring in the 3:4 position—thus



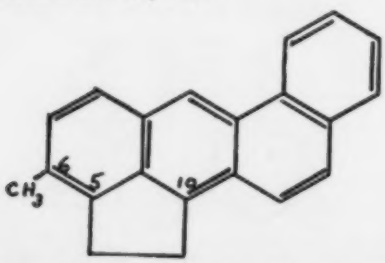
Notice, however, that it also may be considered to be 1:2 benzanthracene



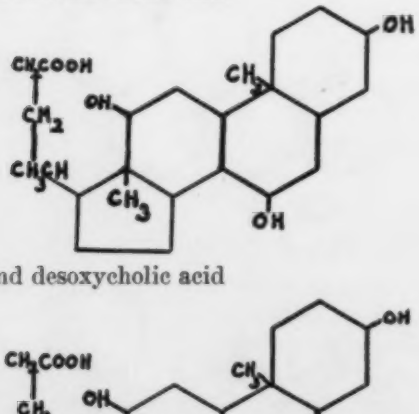
with a benzene ring in the 9 position. This substance has been known to produce cancer in the skin of mice in as little as 30 days. A tumor has occurred in a rat 25 days after subcutaneous in-

jection. It has produced cancer in the mouse in doses as small as 0.4 mg.

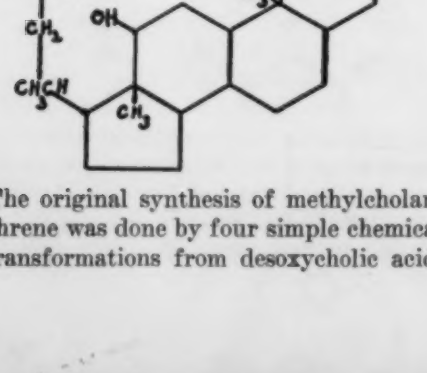
In 1934 a third substance, methylcholanthrene, synthesized simultaneously by Wieland and Dane (in 1933) and by Fieser at Harvard, was found by Cook and Haslewood to be even more powerful as a cancer producer than 3:4 benzpyrene. This compound is of great interest from the theoretical point of view as will appear when its structure is explained. It consists of the 1:2 benzanthracene nucleus (see last diagram) to which is added a methyl group at position 6 and a cyclopenteno (five-membered) ring at position 5 and 10, thus



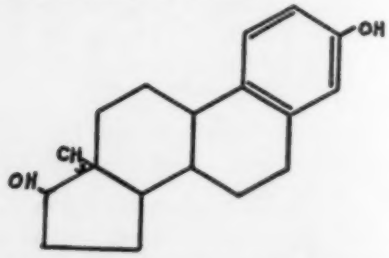
Now the two principal acids occurring in bile are cholic acid



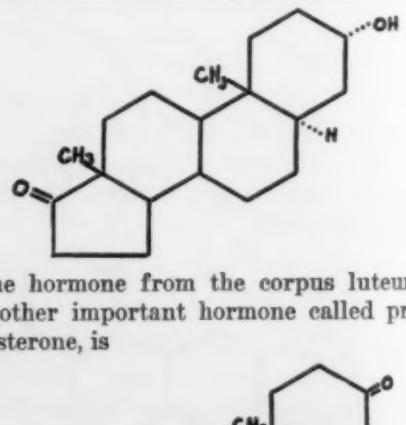
and desoxycholic acid



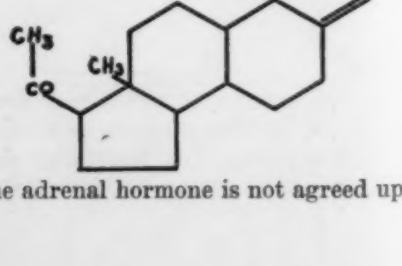
The original synthesis of methylcholanthrene was done by four simple chemical transformations from desoxycholic acid. Later Fieser and Newman at Harvard reported a similar series of transformations from cholic acid. This immediately suggests that cancer arises in human beings as a result of similar reactions taking place in the body, changing cholesterol or one of its derivatives, the bile acids, into a cancer-producing substance, such as methylcholanthrene which in turn produces the cancer. This hypothesis was particularly attractive since many of the substances, known as sterols, which are of great importance in the body have chemical structures which suggest the above diagrams. For instance, the female sex hormone from the ovary, oestradiol, may be written



and the male hormone, androsterone, so

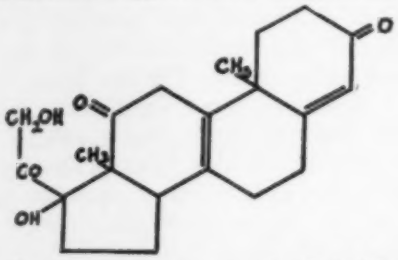


The hormone from the corpus luteum, another important hormone called progesterone, is

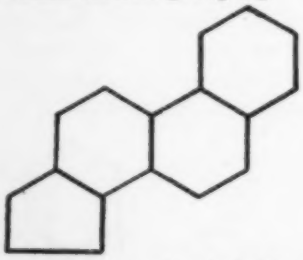


The adrenal hormone is not agreed upon

but Marker suggests that its formula is



Similar formulae represent related hormones, such as oestrone and oestriol, two other female sex hormones, and testosterone, a male hormone. Vitamin D is derived from ergosterol and it in turn has the characteristic grouping.



The same is true of alkaloids of the digitalis and saponin groups, substances having very marked physiological actions.

However, it is one thing to point out superficial structural resemblances of these substances and quite another to say that transformations of one into another take place in the body, even though in the test tube one can make methylcholanthrene from the bile acids. Can or does such a thing occur in the body? Our evidence must be very indirect in lieu of more studies not yet made, although already begun, on the changes undergone by both carcinogenic chemicals at one end and hormones at the other. What sort of evidence do we have?

First, it is interesting that benzpyrene will give the same hormonal effects as the female sex hormone, that is, it will produce the state known as heat or oestrus in the castrated female mouse or rat; the female will accept the male though she will not do so if she is castrated and untreated or even if she is normal unless she is in heat. This same effect is produced by another carcinogenic hydrocarbon, 5 : 6 cyclopenteno 1 : 2 benzanthracene. However, the significance of these observations is greatly diminished when we find that it takes very large doses of the cancer-producing hydrocarbon to cause oestrus, much larger than needed to yield cancer, and this property is shared by many substances quite unrelated chemically to either the sex hormones or the cancer-producing substances.

Another approach to the problem has been made by the successful production of cancer with the hormones. Nevertheless the conclusions we reach from this line of attack must be very guarded as will be seen.

The story goes back to some work of Leo Loeb, who first showed that if one started with a pure-bred race of mice, in which a large proportion of the females developed cancer of the breast if they lived long enough, and castrated the females before they were three months old, very few would subsequently develop cancer. The corollary of this was provided by the work of Murray, who transplanted ovaries into young castrated male mice of high cancer strains and so produced cancer of the breast in a few of these animals when they grew old. Lacassagne, working on these observations, injected female sex hormones into male mice from high cancer strains, and by starting when the animals were 10 days old and giving the largest possible doses he was able to produce a high proportion of breast tumors in the surviving animals. These male mice almost never develop breast cancer spontaneously.

But notice that this experiment will only succeed in animals in which the females show breast cancer spontaneously, only in animals injected with the largest possible doses from a very early age, and

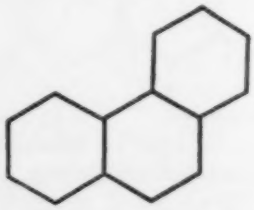
that the cancer occurs in the breast and not at the site of application of the hormone. The female sex hormones have the ability to produce marked development of the breast tissues and it is yet to be proved that these cancers occur directly as a result of the action of the hormone. Perhaps the hormone merely develops the male mouse's breast to such an extent that it becomes like the female's, a fertile soil, so to speak, for some other agent to work on and cause the cancer.

Lacassagne, the Yale workers, and MacEwen all report occasional cancers of the connective tissue or fat at the site of hormone injections, suggesting a direct cancer-producing action of the hormones. However, these always have been injected repeatedly in an oil solution and it is well known that the injection of oil alone in rats and mice, repeated often enough, will cause an occasional cancer.

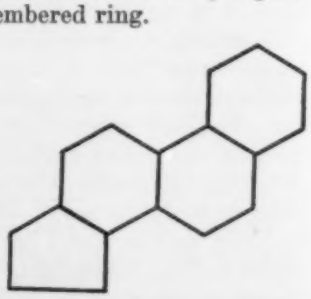
So far we know very little about the changes taking place chemically in the female sex hormones after injection into the body. For the most part they are acted upon very quickly; only a fraction of the material injected can be recovered in recognizable form. As yet we do not know enough to say that they are ever changed in the body to resemble any of the known cancer-producing substances.

It is well to say here, parenthetically, that the danger of causing cancer in women with these materials used as medicines is yet to be demonstrated. Cancers in animals are only produced when the drugs are used in the largest concentrations possible without killing the animal, in repeated injections from early in life to the death of the animal and do not succeed if started in adult animals. No authentic cases are recorded in women. Occasionally one hears of a woman developing cancer of the breast or uterus after intensive hormone treatment but closer investigation usually shows any connection between the two to be quite unprovable. Either the cancer was probably present before the injections were given or the dose was too small to conceivably produce the tumor, or the simultaneous development of the tumor with the injections was coincidental. Those who have given the largest amounts to the greatest number of cases all seem to agree that in their experience they have seen no cancer developing from the therapeutic use of hormones.

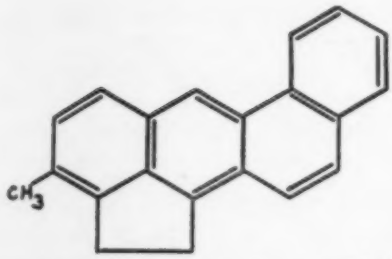
We come now to a brilliant piece of research attempting to answer the same question, *i.e.* whether cancer production and the naturally occurring sterols are related. The chemical syntheses were carried out by Fieser and his coworkers while M. J. Shear did the animal experimentation. You will have noticed that all the sterols mentioned above had a phenanthrene nucleus



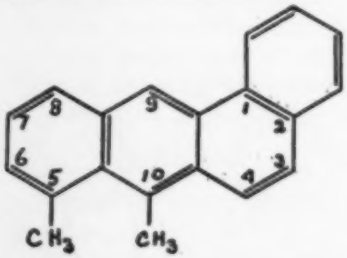
to which was added a cyclopenteno, or five-membered ring.



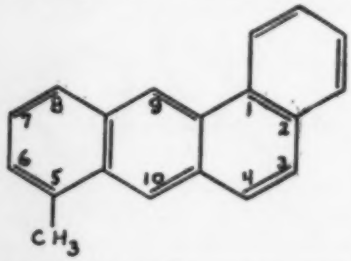
If this ring, which occurs in so many biologically active substances, were shown to be of importance in cancer production it would link the latter more closely to the sterols in the body. To answer this question Fieser prepared a series of substances which were tested by Shear for their cancer-producing quality. The formula of methylcholanthrene, you remember, is



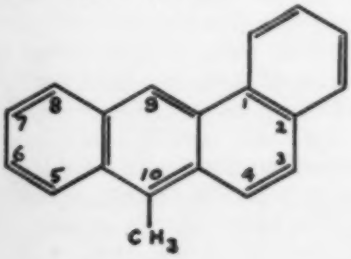
Fieser first made cholanthrene which is similar but lacks the methyl (CH_3) group. Removal of this group was found to affect the cancer-producing property of the substance very little. Next he split the five-membered ring, making 5:10 dimethyl 1:2 benzanthracene.



Here he had gotten rid of the ring but found that he had retained the cancer-producing potency. Finally he made both 5 methyl 1:2 benzanthracene

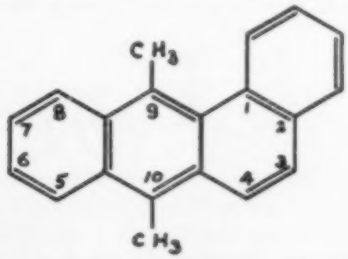


and 10 methyl 1:2 benzanthracene.



Of these, the 5 methyl compound was weakly cancer-producing while the 10 methyl compound was almost as potent as methylcholanthrene itself. And so he had proved that methylcholanthrene is a strong cancer-producing agent, not because it has a five-membered ring and is related to the naturally occurring bile acids, hormones and vitamin D, but because it is a 1:2 benzanthracene with a substitution group in the 10 position. This demonstration weakens, though it does not abolish, the theory that cancer arises in the body from the formation of a cancer-producing compound by the faulty metabolism of one of the sterols.

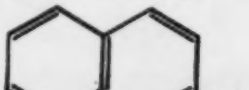
The subsequent course of this research both by Fieser and Shear and by the London group has led to the synthesis and testing of all of the possible monomethyl substitution products of 1:2 benzanthracene. It has been found that only the 10, 9, 5, 6 and possibly 7, compounds are cancer-producing and in that order of potency, 10 methyl 1:2 benzanthracene being the strongest. Remember that benzpyrene may be considered a 9 substituted 1:2 benzanthracene. This last year, 9:10 dimethyl benzanthracene has been made and has been found, as one would expect, to be the most potent substance so far obtained in giving cancers of the skin in mice, although, strangely, it does not cause connective tissue tumors.



It would be wearisome and perhaps meaningless to describe or even list all the substances related to 1:2 benzanthracene or phenanthrene which have been found to be cancerigenic. Suffice it to say that in a recent review, Fieser lists 49

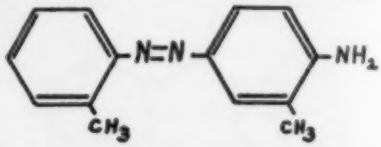
which have been reported as giving tumors, at least by one worker. How many of these will stand the test of time and how many are really cases of tumor caused by the oil in which they were injected is hard to say. At any rate they merely add, for the most part, a long series of pure chemicals as causes of cancer formation to the list of other stimuli which we have known from clinical and laboratory observation to be cancer producers. One point which should be brought out in passing is that perhaps the reason the chimney-sweep's cancer and the tumors Volkmann described in tar-workers only occurred on the scrotum is that most of these materials are fat-soluble and not water-soluble. In the skin of the scrotum are very abundant sebaceous glands often containing a large amount of fatty material in which the cancer-producing hydrocarbons could readily dissolve and be kept in contact with the tissues for long periods of time.

We turn now to a number of hydrocarbons which are most interesting because they produce tumors not at the site of their entrance into the body but in some distant organ or tissue. They are related to the substances of which we have been speaking in that they are all derivatives of coal-tar but otherwise they are structurally quite different. The simplest of these is beta-naphthylamine long

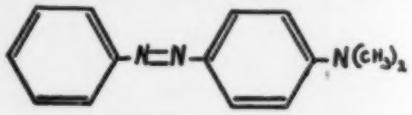


suspected as the cause of tumors of the bladders in anilin dye workers and finally used successfully in the production of such tumors in dogs by Hueper, Wiley, and Wolfe in 1938. The drug was given subcutaneously or by mouth. The tumors were in the bladder.

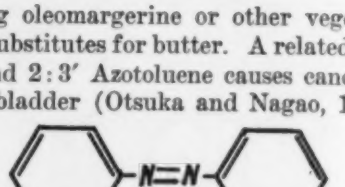
In 1935 Sasaki and Yoshida, two Japanese workers, injected O-aminoazotoluene under the skin of mice and obtained



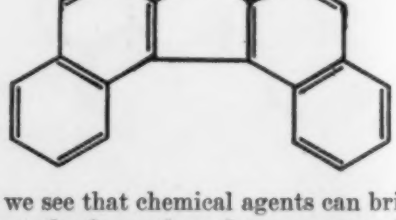
thereby tumors of the liver. Similar tumors were produced by Kinosita in 1937 with P-dimethylaminoazobenzene, a substance known as "butter-yellow" and used commercially as a dye for col-



oring oleomargerine or other vegetable fat substitutes for butter. A related compound 2:3′ Azotoluene causes cancer of the bladder (Otsuka and Nagao, 1936).



3:4:5:6 Dibenzcarbazole produces not only cancer of the skin at the site of application but also tumors of the liver according to Boyland and Brues (1937).



So we see that chemical agents can bring about the formation of tumors at a distance as well as at the site of application and in this group will be included the hormones, if some day they are proved to be themselves truly carcinogenic.

It is all very well to list the various ways one can produce cancer and it is very nice to be able to make cancers with some pure chemical, the name of which

most people cannot remember or pronounce, but neither procedure answers the great questions of why and how these substances work. Are we any nearer to the secret of unrestrained growth or the prevention or cure of cancer, or have we merely listed a new set of industrial hazards related to coal-tar? Here we are truly in a practically unexplored field. A few tentative lines of research have been thrown out but so far they do not lead a great way. Haddow, for instance, finds that all of these potent hydrocarbons are inhibitors of cell growth. One can stunt a young animal permanently by injecting it with methylcholanthrene. Often the cancer-producing chemical can be told from one which does not produce cancer before either is actually tried out by seeing what effect it has on the weight curve of young growing rats. So marked is this growth inhibiting effect, in fact, that these hydrocarbons have been used to treat locally clinical cancer in man, with a modicum of success. It slows up the local growth.

Haddow points out that if one keeps certain bacteria of the typhoid group under unfavorable conditions (by keeping them growing a long time on the same culture media) some will suddenly change and become able to utilize types of sugars in the media which they previously were not able to use as food. He draws an analogy between this and cancer production. The cells in contact with the cancer-producing hydrocarbon are not killed by it but some of their life processes (perhaps some of the enzymes connected with cell respiration) are interfered with. The cell fails to grow and has difficulty in surviving until suddenly it mutates or changes in some unknown way and becomes able to use as food, tissue juices or blood plasma which previously it could not. Such a change would result, possibly, in unrestrained cellular proliferation, the process we call cancer.

Fieser has attacked the question from the purely chemical side and points out that while the potent cancer-producing compounds related to benzanthracene are rather inert chemically, they can be attacked and oxidized by lead tetra-acetate and can be diazotized and both of these reactions take place at the positions on the benzanthracene nucleus which are of the greatest importance in making potent compounds, the 10 and 9 positions. He believes cancer-producing potency to be related to some peculiar chemical reactivity greatest at these points.

Boyland and Levi, and more recently Rhoads and Dobriner, have tried to find out what becomes of 1:2:5:6 dibenzanthracene in the body and have discovered that animals which differ in their susceptibility to this substance differ in the way they metabolize and excrete it. The rabbit, though tumors of the skin were first produced in it, is very resistant to the action of any of the cancer-producing hydrocarbons when they are injected under the skin. Only one paper has reported the successful induction of such tumors and even then only in a few animals. Is this resistance related to the fact that the break-down products of dibenzanthracene in the rabbit are entirely different from those in the rat or mouse?

Nakahara, using "butter-yellow" in rats, says that those fed a large amount of liver or yeast fail to get the cancers of the liver which appear in the control animals. Does the cancer-producing action have something to do with vitamins, especially the B complex which occurs in abundance in liver or does it inhibit liver cell destruction and the consequent regeneration which goes over into cancer? Pure vitamin B does not have this protective action. Possibly a very fertile field would seem to lie ahead of the person looking for the effects of various vitamin-deficient diets on cancer production with hydrocarbons. It is almost unexplored.

At the last meeting of the American

Association for Cancer Research, G. H. A. Clowes reported some very interesting experiments in which small additions of benzpyrene and methylcholanthrene produced marked changes in the physical characteristics of monomolecular films of cholesterol and ergosterol, suggesting that these substances act by altering the nature of the cell membranes where lipids play such an important role.

Where will the search lead us? Here is the chemical. How is it changed in the body? What does it do to the cell? How is it related to the virus of fowl tumors, if at all? A thousand questions arise. How tantalizing to see the changes taking place in the animals' cells right under our eyes as we gaze through the microscope and not to be able to say how or why!

It seems necessary to offer an apology for such a cursory survey of so vast a field. We have described only a few of the important points and have undoubtedly failed to mention many discoveries of the utmost value.

It often seems to me that cancer research can be likened to the exploration of some vast unknown island such as New Guinea. We can sail around it and land on any side to try to make our way into its inner fastnesses. The easiest lanes into its interior are like rivers leading up toward the mountains of promise. Pott, Volkmann, and Yamagiwa were the bold explorers who first charted the mouth of one of the rivers. Others have sailed up it many miles, and we have just been with them to the head of navigation and seen some of the tributaries up which men are forcing their way, knowing not whither they lead. We have said nothing of the other great rivers, such as the genetic attack, the virus approach, the stream of pure physical research, or that of endocrinology, though we have taken a brief peek over the watershed into that valley. Ofttimes the men trying to beat their way inland from that hard and rockbound coast called clinical research, characterized by its difficulty but perhaps by its closeness to the final secrets, wonder whether those on the other side of the island, sailing the rivers are really exploring the same island or heading for the same goal. "What has tar to do with the cause and cure of cancer in my patients?" exclaims one. Or "How can rats and mice or fruit flies mean anything to me?" says another.

Some explorers go off into the wilderness alone and return with strange and fascinating tales, often true but hardly believable until seen by others. Many such tales are no more than mirages or the figments of vivid imaginations told to the admiring public and, as Pott put it, "more calculated to enable men to talk than either to judge or to act."

The quest is vast and alluring. Streams asking to be explored lead away on all sides. One must try to pick the largest and most navigable if one is to do more than become lost in the dense jungle. The quest is exciting and moves rapidly. Treasure may lie anywhere. One wishes for six heads to hold all the knowledge he needs, a hundred hands, the best equipment, and 48 hours in a day. When will the goal be reached or will it ever? Who knows? But how exciting to go and try!

THE SPACE IN WHICH WE LIVE

By Dr. PAUL R. HEYL

NATIONAL BUREAU OF STANDARDS, WASHINGTON, D. C.

OUR ideas of the space in which we live have undergone a development or evolution in common with our ideas of all the other wonders in nature round about us. Primitive man's attempts to explain natural phenomena were animistic, often anthropomorphic. Each tree was inhabited by a spirit or tree-nymph, called a dryad; the electrical properties of amber were due likewise to an indwelling spirit who could be roused to action by the rough treatment of friction; Roger Bacon, the greatest scientific mind of the thirteenth century, still held to the ancient belief that the heavenly bodies were carried about by angels. Such primitive scientific theories had the advantage of being readily understood by everybody, which is more than can be said of their modern successors. Scientific theories have followed Spencer's formula in their evolution, proceeding "from the homogeneous to the heterogeneous," from the simple to the complex, and have now in some cases reached a degree of complexity which makes them incomprehensible to the multitude and rather appalling even to those professionals who feel that they must make the attempt to follow their development.

In man's earliest ideas of space there were two characteristic features. One was its geocentric architecture. It was a natural induction from the apparent motions of the heavenly bodies that they all revolved about the earth as a center. Such a theory, moreover, by placing man at the center of the universe, tickled his vanity, and furnished a powerful motive for the opposition to the later Copernican astronomy.

A second characteristic of space as conceived by early man was its finite and relatively small extent. It is difficult for us, familiar as we are from childhood with the idea of the immensity of space, to realize how small the ancients thought the visible universe to be. The Greeks placed the abode of the gods no farther away than the summit of Mount Olympus; Omar Khayyam speaks of

> that inverted bowl we call the sky,
> Where under crawling, coop'd we live and die.

The legend of Mohammed's nocturnal round trip from earth to heaven, mounted on a miraculous steed, was a natural outgrowth of the limited idea of space common in his day. Such a story, even when colored by the supernatural, would have been incredible and could not have taken root in the background of such space ideas as those with which we are familiar. The proud boast of the builders of the Tower of Babel, "Go to, let us build a tower whose top shall reach unto heaven," is not to be regarded entirely as a figure of speech.

The change from these ideas to those prevalent to-day has been so revolutionary that we have not yet entirely adjusted ourselves to it. The world of the ancients, at the center of a comparatively limited universe, was a rather cozy and comfortable place. The sun, moon and stars shone for man's especial benefit and pleasure; the gods were never so far away that they could not drop in unexpectedly for supper, if they felt so inclined. Contrast this with the position in which we find ourselves. We are but microscopic parasites on the surface of an insignificant planet, attached to a third-rate star. About and beyond us space stretches its dizzying immensity, be-

strewn with stars like our sun, some larger and brighter than our luminary, others much smaller. Our cosmic emotion to-day contains an element of loneliness. We have so much more room than we really need, and our nearest neighbors are so far away! Nevertheless, we must make the best of our situation, and perhaps we shall be most successful in this if we follow the scientist's way, and learn what we can about this great and wonderful space and its contents.

The visible contents of space, the sun, moon, stars and planets, have been the objects of man's study and attention from remote antiquity, and this study has not been without its fruits. We have learned to measure the distances of the stars, and even to make chemical analyses of the glowing gases that make up their atmospheres. We have found that the brightest stars are not necessarily the nearest to us, and that the so-called "fixed" stars are actually in motion with high velocities, which great distance renders almost imperceptible. We find stars grouped together in clusters and nebulous patches, such as the Milky Way. Some of these nebulae can be resolved by the telescope into their star-components; others, irresolvable in this way, have been shown by the spectroscope to consist of large masses of glowing gas.

Many of these nebulae, on spectroscopic evidence, seem to be receding radially from us in all directions, with velocities which increase with their distance. This extraordinary state of affairs has raised a question as to the proper interpretation of the spectroscopic evidence. Are we to interpret it as we usually do in the case of bodies comparatively near us or is there some hitherto unrecognized law of light which over an immense distance of travel simulates the optical effect of a receding body?

We do not know as yet, but for the sake of those of us who are cosmically minded it is to be hoped that these velocities of recession are only apparent. If real, it would be a blow to our self-esteem, for it would suggest that in the distant past these nebulae were so near us that they learned all they wanted to know about the way in which man conducts his affairs on this planet, and have never stopped running.

Among the most interesting bodies in space are those which we can not see at all—the dark stars and nebulae. Such dark stars as we have been able to detect are parts of a double star system, the light of the bright component being periodically eclipsed by the dark star in its revolution about it. It is probable that many other dark stars exist which we have no means of recognizing.

Dark nebulae are also to be found here and there, becoming evident when they are seen as dark patches against the background of a luminous nebula. One of these black regions, known as "the coal sack," caused the astronomer Herschel, when it drifted into the field of his telescope, to exclaim to his sister: "Surely, here is a hole in heaven!"

Stars, star clusters and nebulae, bright and dark—such are the contents of the space in which we live. These are wonderful indeed, but the very space itself, in which they live and move and have their being, is a greater wonder and a more mysterious puzzle.

Our earth circles round the sun at the rate of 18 miles a second. What force holds it in its orbit and prevents it from flying off at a tangent, like drops of water from a rapidly rotating grindstone? The force of gravitation, we say. We repeat these words glibly, but do we realize the magnitude of this force? Calculation shows that the centrifugal force of the earth in its orbit would snap a steel cable 5,000 miles in diameter! And yet space, "empty" space, holds the sun and the earth together.

But this is not all. Let us pile Pelion upon Ossa.

The earth receives from the sun a continual stream of light and heat, representing in the aggregate a large amount of energy. How does this energy get across the empty space between the sun and the earth?

Lodge, in discussing this question, puts it in this way. Suppose there is a dog lying asleep a few feet from us. How can we attract the dog's attention? We might prod him with a stick; we might throw a stone at him, or we might whistle or call to him. In either of these ways we might convey sufficient energy to the dog to furnish the needed stimulus.

In the case of the sun and the earth the stick is obviously ruled out of consideration, but the stone is a possibility to be considered. In Newton's day and for a century afterward it was believed that light consisted of a stream of very minute corpuscles shot out from the luminous body. This theory accounted well for the straight line travel of light and for several other facts of observation, but there were difficulties also. One of these was encountered when it was discovered that light traveled with the enormous speed of 180,000 miles a second. Speaking in modern terminology, a particle weighing one millionth as much as a grain of sand, and traveling with the speed of light, would have as much energy as a rifle bullet. How could such a delicate organ as the eye withstand machine gun fire of this nature for a lifetime without injury? The only possible answer was that the light corpuscles must be inconceivably minute; and since indefinite retreat was possible in this direction the corpuscular theory, though severely shaken, managed to hold its ground for the time being.

Early in the nineteenth century another and a more serious objection was encountered. It was found that two beams of light traveling in the same direction might actually extinguish each other and produce darkness. This finally disposed of the corpuscular theory of light.

The third alternative method of rousing the dog now comes up for consideration. Perhaps light may travel in some such way as sound.

The nature of sound is quite well understood. It travels through the air somewhat as a train of waves travels in water. Light objects floating on the water merely rise and fall as the waves pass, showing that there is no forward motion of the water as a current, but merely a vibratory rise and fall. Only the form of motion moves onward.

A somewhat similar vibration takes place when sound passes through air. When the sound wave reaches the ear of the dog it sets the drum of the ear in motion, and this in turn excites a nervous impulse which creates in the brain the sensation of sound.

But sound will not pass through a vacuum. It is a common lecture experiment to place an electric bell under the receiver of an air pump and exhaust the air. The sound of the bell becomes fainter as the exhaustion progresses, and finally ceases to be heard. Sound waves require a medium for their transmission, yet light vibrations come to us from the sun across ninety million miles of empty space. Is space as empty as it seems to be?

The phenomena of both gravitation and light lead to the same question: "How can a body act on another across empty space?" The utter inconceivability of action at a distance gave rise to the hypothesis that space was not really empty, but was filled with a medium to which was given the name of the ether.

The properties that had to be assigned to this hypothetical ether to make it fit the facts of observation were not only strange but incompatible with each other. The first difficulty to be met was that such a medium might naturally be expected to cause a retardation in the motion of the heavenly bodies. Such a

retardation in the case of the earth would cause it to spiral gradually inward toward the sun, with an accompanying change in the length of the year. No such retardation has ever been detected.

But the earth is perhaps rather a massive body for such a test. A much more delicate test is possible in the case of comets, which are largely gaseous in composition, but even here the evidence is negative.

To account for the absence of any retarding effect two assumptions were made about the ether; first, that it was absolutely frictionless, and second, that it was tenuous to a degree unparalleled in our experience of material substances.

Such assumptions were logically necessary, but led to a serious contradiction; for if the ether could exert no retarding effect on bodies moving through it, how could it exert the accelerating effect we call gravitation? In other words, the ether had to be "ethereal" to the *n*th degree, and at the same time stronger than a steel cable! And in time it was found necessary to assign to the ether other attributes equally inconsistent. As a result, toward the close of the nineteenth century there prevailed an uneasy feeling that we were on the wrong track; that, like Frankenstein, we had invented a monster which was getting out of control. Yet to abandon the idea of the ether was to be confronted with the equally inconceivable idea of action at a distance. Here was a dilemma, indeed; and what was to be done about it?

In the history of scientific thought it has never happened that we have been long without a theory of some kind when we needed one; and in this dilemma two suggestions were made, one in 1886, by Hinton, whose name is known to but few to-day, and the other in 1916, by Einstein, whose name (at least) is familiar to everybody. It is interesting to note that both these suggestions adopted much the same way out of the difficulty, though in their subsequent development the two theories differed widely.

Both Hinton and Einstein recognized the necessity for a space-filling medium of some kind. They also saw that its frictionless character must be retained. This left its supposed tenuity as the only possible point of attack. The magnitude of the force of gravitation suggests a connecting medium of a rather substantial character, and since there is obviously no room for such a substantial medium in our space as we know it, both Hinton and Einstein placed it where there was plenty of room—out in space of four dimensions.

The concept of four-dimensional space was not new even in Hinton's day. For at least half a century this idea had had a place in mathematical theory. Hinton, however, was a pioneer in its application to physical problems.

Charles Howard Hinton was an Englishman, a graduate of Oxford University. He spent some years as a professor of mathematics in Japan, after which he came to the United States, and held positions in Princeton University, in the University of Minnesota and in the U. S. Naval Observatory. It was my privilege to make his acquaintance while he was at Princeton, and to correspond with him until his death in Washington in 1907. He published in 1886 a book called "Scientific Romances," in which is found much of his four-dimensional theory of the ether.

Imagine a paper doll between two large sheets of plate glass, both glass and paper being so smooth and highly polished as to be frictionless. Suppose the doll to be conscious, and able to move about in his two-dimensional world. All his experience being confined to motion in a plane, he would have no conception of a third dimension. As he moves about he may encounter inanimate pieces of paper of various shapes and sizes, which he calls "matter." He observes that a piece of

such matter if set in motion moves without retardation, and from this he deduces that "space" is "empty."

Now suppose that the glass is tapped strongly at a point some distance away from the doll. A wave motion will be set up in the glass, and when this reaches the doll he will feel it, but will be puzzled to explain how this vibration has reached him from its point of origin. The space around the doll is empty of matter (*i.e.*, paper), and how can there be a vibration without something to vibrate?

This contradiction would be hopeless to a two-dimensional intelligence, but we, with our three-dimensional experience, see at once that there is indeed something very substantial to do the vibrating, something which does not lie *in* the doll's space, but *alongside* it, out in three-dimensional space, exposing to the doll's touch only its smooth, frictionless and imperceptible surface.

Now move up one dimension, by analogy, and we have Hinton's theory of the ether. A two-dimensional figure, such as a square, is bounded by one-dimensional lines; a three-dimensional figure, such as a cube, is bounded by two-dimensional surfaces; and a four-dimensional figure, similarly, would be bounded by three-dimensional solids. And just as the doll's two-dimensional space was in contact at every point with the surface boundary of the solid glass, so our space of three dimensions is in contact everywhere with the solid boundary of the four-dimensional ether.

Hinton discusses the question whether this paper doll could in any way become conscious of his spatial limitation, and points out that there is a way by which he might become aware of a third dimension, depending on the fact that the doll actually has a slight thickness in that direction, though he is not conscious of it.

A piece of paper between two sheets of glass can turn about an axis perpendicular to itself, but not about an axis in its own plane. A circle under these conditions could not turn about its own diameter; but Hinton points out that if the diameter of the circle be very small, less than the distance between the glass plates, it would have perfect freedom of motion, and could then execute the three-dimensional movement of turning about its own diameter.

But a circle thus turned looks the same as before, and if anything of this sort were to happen in the doll's experience there would be nothing to suggest to him that anything unusual had taken place. With an unsymmetrical figure the case is different. A piece of paper in the shape of a lower-case *p*, confined between two sheets of glass, may be turned into various positions

but can never be made to look like a lower-case *q*. To change *p* into *q* requires motion in a third dimension. But if the *p* be so small that the width of its loop is less than the distance between the glass plates, this change might be accomplished.

If the doll should discover that bits of paper below a certain critical size could be made to behave in a way which is impossible (or, as he would say, inconceivable) with larger pieces, he would regard this as an important and significant fact; and if he should be led by this to make a microscopic study of these motions he might have revealed to him the existence of a third dimension.

Considerations of this nature led Hinton to the conclusion that the most likely place to look for suggestions of four-dimensional motion would be in the behavior of molecules and atoms, and during a visit which I paid him at Princeton in 1897 he outlined to me several lines of thought in this direction. For instance, consider the law according to which electrically charged particles act on each other. Under ordinary conditions we find that the force of attraction

varies inversely as the square of the distance between the particles. But if our space had a very small extension in the fourth dimension, and the distance between the particles was less than this extension, there would be geometrical reason to believe that the law of attraction would change to the inverse third power. Hinton also pointed out to me that the change of p into q might have an analogy in the optical behavior of the four kinds of tartaric acid.

Such, in brief, is Hinton's four-dimensional theory of the ether. The physical applications that he made of it include the phenomena of light and electricity, but in neither his published writings nor his private communications to me did he deal with gravitation. It was left for Einstein, thirty years later, to propose a theory fundamentally much like Hinton's, and apply it successfully to gravitation.

Imagine a smooth flat frozen surface of a lake. Assuming friction to be absent, a stone set in motion over this surface would move in a straight line with uniform velocity. If we observed the path of the stone to depart from a straight line at any point we might reasonably infer that there was a slight elevation or depression of the ice at that place, even though we could not clearly see it from where we were standing. Now suppose there to be a large, heavy stone resting on the ice, producing a depression or cusp in the surface in its neighborhood. At some distance away, where the ice is again flat, suppose a small stone, which produces no appreciable cusp, is set in motion in such a direction as will carry it past the heavy stone at a short distance from it, well within its cusp. The path of the small stone, at first a straight line, will, as it enters the cusp, gradually assume a curved form. Assuming no attraction to exist between the large and the small stone, the latter will pass on and out of the cusp, its path again becoming straight; but on account of the brief twist to which it was subjected the latter portion of its path will not be in the same direction as the first. The small stone will have suffered a permanent deflection.

An observer watching the motion of the small stone through what we may call Newtonian spectacles, which do not show him the curvature of the ice, will say: "Yes; on passing the large stone the small stone seems to have experienced a force of attraction which has deflected it from its straight path." But let him replace these glasses by others of Einsteinian make, and he will say, "No, I see now that there was no force of attraction at all. It was purely the inertia of the small stone combined with the curvature of the surface that produced the change in its path."

If the small stone passed very close to the large one it might not be able to get out of the cusp at all, but would circle round and round, like a planet round the sun.

This theory of Einstein and that of Hinton are fundamentally similar. The motion of the stone over the ice and that of the paper between the sheets of glass are both subject to a constraint which limits their motion to two dimensions. But Hinton considered only flat space, while Einstein added the idea of space curvature, which gives rise to an effect which we call gravitation.

Applied to the space in which we live, Einstein's theory contemplates a space curvature in a fourth dimension analogous to the curvature of the ice surface in a third dimension. Einstein regards our space as normally "flat," but warped or distorted around every lump of matter, large or small. The great mass of the sun produces a space distortion which reaches beyond the

planet Pluto, and captures an occasional comet that happens to come within range.

The concept of space curvature, like that of a fourth dimension, to which it is closely linked, is older than either Einstein or Hinton, but had always been confined to the realm of mathematical theory. As applied by Einstein to physical problems it has been remarkably fruitful. In addition to offering an explanation for gravitation it enabled Einstein to predict two physical phenomena which had never been observed, but which have both been subsequently confirmed by observation. One of these was that a star nearly in line with the sun, as seen at the time of a total eclipse, should appear displaced from its true position. A ray of light from a star traverses millions of miles of space remote from material bodies, and consequently "flat." In this region the path of the ray is a straight line. But close by the sun, whose great mass causes a considerable warp in space, the path of the ray is bent, and when it again becomes straight it has been permanently deflected from its original direction.

It is interesting for one who remembers Hinton to compare the reception accorded his ideas with that which has been the guerdon of Einstein. In talking with Hinton's colleagues and students, ten or twelve years after the publication of "Scientific Romances," I found the opinion prevalent that the fourth dimension might be all right in its place as a mathematical theory, but physically – – – ! Only one generation later, when Einstein again brought the fourth dimension into physics, his reward was world-wide fame and a Nobel prize. *Tempora mutantur!*

There is much more that might be said about the space in which we live, but perhaps I have said enough to justify my earlier statement that empty space is a greater wonder and a more mysterious puzzle than its visible contents.

SCIENCE IN AN UNFRIENDLY WORLD

By Dr. W. JAMES LYONS

NEW ORLEANS, LOUISIANA

THAT there are prevalent in the world to-day certain trends of thought and action unfavorable to the future prosperity of science needs no extensive proof. The sentiments range from a general coolness toward technological advance to an active antipathy toward a free science. Each challenge, separately, has been recognized and identified with more or less adequacy, but a more comprehensive view of them as parts of what is in effect a more general movement is lacking. While it may be said that one of the challenges to science merely implies "friendly competition" of a sort, or that another is only a vague rumbling, they deserve a brief consideration by the student of affairs, as well as by the scientist. Because they are not isolated in time, but confront science together, their significance is enhanced. It is not my intention, however, to "uncover with alarm" an immediate danger or one of appalling magnitude.

These current dangers to science are clearly distinguishable from each other. The first, specifically, is the attack on the dominant positions which science, and the *scientific method* have come to achieve, during the past seventy years, in the national philosophy of education. The most prominent and energetic leader of this thrust is, of course, Robert Maynard Hutchins, of Chicago, whose ideas have been developed in numerous publications and addresses. The second adverse trend, less well-defined, is a growing coolness toward science, and suspicion of it, in the public mind, more markedly at the low-income level. The subtle nature of this threat precludes its having any leaders. Aside from some political talk about declaring a legal holiday for invention, the attitude is yet largely negative. What well may be taken as the representative attitude in this respect has been presented sympathetically by Norman Foerster.[1] Finally, science is confronted with the demoralizing programs of the totalitarian governments. The problem for science here is not the cruelties and injustices which have been inflicted on scientific workers in those countries on account of race or religious creed, reprehensible though such activities are. But a problem and a threat to free science does exist in the system of regimentation and delimitation, of thought and inquiry, in vogue in the dictatorships.

These three unfavorable currents, in common, reflect a lessening in the prestige which science has enjoyed for decades. They reflect, it would seem, a conviction spreading vertically and horizontally that science in one or another of its aspects is not as worthwhile to mankind as it had seemed to be. Whether, further than that, any causal or logical relationships between them exists, I am not prepared to say. It does not appear, however, that the existence of such relationship is pertinent to the present discussion.

Bound up with the question of whether scientists are meeting these challenges satisfactorily is the one whether some of the criticisms or attitudes are justified. What has become the traditional mode of pleading the case for science is to point with pride to past achievements and to predict a future of more abundant crea-

[1] "The American State University." Chapel Hill: University of North Carolina Press, 1937.

ture comforts and less pain. A latter-day expansion of this theme has been an invitation to the world to put itself in the hands of science for the great cure of all spiritual, economic and social ills. Perhaps this proposal is in the nature of a counter-offensive. But the whole argument is becoming a little worn and empty. It was effective thirty years ago, but is not pertinent to the dominant interest of the troubled world of to-day. Some of its implications have been rather badly riddled by observers of the modern scene.

But what can and ought the apologists of science say or do in its behalf?

I

It is true that the analysis and criticism of Dr. Hutchins and his associates are focussed on the theory and pattern of higher education which the American system had evolved by, say, 1930. Nevertheless, science is greatly implicated, since the dominant theme in that theory was the *scientific method*. In the reaction against the indoctrination which characterized earlier practice in higher education, objectivity and the empirical basis of knowledge were now emphasized. Less and less, with the passage of time, was there a willingness to teach anything that could not be rigorously proved. Norms for evaluation and appreciation became themselves subjects for dissection and objective analysis. The emphasis turned to equipping the student with a fund of specialized knowledge, and the special techniques by which more facts could be uncovered.

This concept of education the new critics have branded as anti-intellectual. It is claimed that in the modern teaching of science, reason has been suppressed, in deference to the accumulation of an ever-expanding body of facts.[2] In consequence, then, of the influence which science, as well as some other factors, has had on education, we are told that the modern college graduate has lost the art of thinking and knowing. The factual deposits which have been left by his collegiate sojourn lack integration in any broad sense. He is without general principles and standards according to which he may recognize, understand and evaluate the large variety of problems with which he will be confronted in later life.

This case against science, materialism and the elective system in higher education has not been unconvincing. More than one college has hastened to revise its curriculum and, in re-announcing its aims, pay tribute to the *disciplined mind* —a term which a few years ago connoted the extreme of intellectual atrophy. It is the theory of the New Program, says Stringfellow Barr, that "In addition to being able to read, write, and reckon more skillfully and fruitfully than the American college graduate of to-day commonly does, in addition to being able and willing to face present issues, he should be able to recognize those eternal problems which his ancestors faced before him and which recur for every generation of human beings. . . . Experience had taught that the best statements of those problems are the 'classics' of human thought."[3] The variance between the point of view and mode of thought here disclosed, and the modernistic and iconoclastic, scientific attitude is readily apparent.

Not unlike the advocates of science in education, the new humanists appeal to the democratic traditions of American society.[4] Only a system of liberal education, embracing the humanities to an

[2] Robert M. Hutchins, *International Jour. of Ethics*, January, 1934.

[3] *The Key Reporter*, autumn, 1938.

[4] Compare, for instance, Dr. Millikan's statement at Reed College, *The Key Reporter*, autumn, 1938, p. 5, with those of Dean Marjorie Nicolson and Roscoe Pound in a recent symposium, *The Key Reporter*, summer, 1939, p. 1.

important degree, it is indicated, can free men's minds, and safeguard their freedom of thought and speech.

None of the new curricula designed for a more humane education appear to have completely eliminated mathematics and the sciences. With varying prominence, these branches of knowledge are given places in the courses of study. Their *purity* is the norm for admittance. But the sciences are under surveillance, if not suspicion. No longer, under the new plans, are they to be the pacemakers or patterns for the literature, philosophy and history courses. There is a feeling that science as a whole, after sixty or seventy years, has forsaken culture, even civilization.

Scientists and technologists, particularly those associated with education, would do well to recognize that much of the rationale of the new humanist movement is sound. It appears that only by first doing that are they likely to get an attentive audience.

It is fairly certain that there has always been a demand, of varying vigor, for a type of education which looks to the development of the whole individual. The old *classical* education of a hundred years ago attempted to meet this demand by reducing all graduates to one accepted type, the conservative, respectable, widely but vaguely informed gentleman. All facets of the personality were polished, albeit none very brilliantly. But while every educational theory has embraced the idea of well-rounded development, as an ideal at least, the modern, scientifically-inspired higher education has, in practice, avoided the responsibility of itself pursuing that objective. Under the urge to advance and spread impersonal, scientific knowledge, the colleges and universities, their faculties and curricula, have lost sight of the individual personality. Thus, while higher education at its best has been producing rather well-equipped scholars and research workers, in so far as it has contributed, the graduates are without any well-formulated objective in life, are unconscious of their moral and social responsibilities, have no confirmed esthetic or cultural appreciations. Even the functions which the colleges have been performing well lose much of their attraction when it is realized that but few of their graduates are associated with scholarship or research in later life.

The scientist-educator, rather than continuing to proclaim the adequacy of scientific knowledge as the framework of higher education, will render a greater service to society, and to the cause of science ultimately, if he will cooperate in the design of curricula which more effectively meet existing needs. Such curricula will aim to realize, within the bounds of each individual's capacity, men of enlarged vision, sensibilities and intellect. To accomplish this will require a re-orientation of science education; some "scientistic" dogmas will have to be shed, and some concessions made to the non-scientific branches. There is need for a renewed recognition of the limitations of science, particularly in the fields of human relations and conduct. Here the point of view which continually stresses standards of good citizenship and moral responsibility, is more profitable to the average student than is the indifferent, factual and analytical approach, which aims to be *scientific*. Many elementary courses employing this approach never get far beyond describing the approach itself, and conclude by leveling all standards and principles. The student gains nothing positive.

All too often have advocates of science discounted and disapproved whole sections of the cultural deposit of the race, largely because they were accumulated by non-scientific methods. In many of these fields science is still groping for an effective approach, and has thus far

established only general, abstract principles. Whatever motive is associated with this immature sort of science can not be its own. Realism would dictate that here science can not yet offer a workable substitute for the structure which men have built up from experience and expediency, by trial-and-error, hammer-and-tongs methods.

While educators and scientists may wisely make concessions to the non-scientific branches, nothing indicates that all claims for modern science should be relinquished. It must be recognized that the physical and biological sciences have made contributions of facts and generalizations about nature, with which, for tangibility and value, the unhampered speculation and magic of earlier ages have nothing to compare. Educators may well take precautions against the current movement leading back to the old type of classical training. This type of education, adapted to an aristocratic society, and accepting ignorant bliss for philosophic calm, has tended to train narrow-minded and snobbish young men and women.

II

The historians of science are responsible, it would appear, for the unpopularity of science among those most acutely affected by the depression. In their clamor to enhance the scientific tradition, and hoard for science all credit for the remarkable and unprecedented material advances which studded the century and a quarter preceding 1930, these historians have been more enthusiastic than accurate. The steamboat, the locomotive and railroad, the power mill, the telegraph, etc., were all hailed as triumphs of the scientific method. Passing over the inaccurate and illusory nature of this interpretation of technical and commercial progress, the fact remains that it achieved wide currency. In the more intellectual circles, technology and the development of new commercial practices were credited with facilitating the adaptation of science. But, as the doctrine filtered on down through the schools and the press to become a part of the prevailing thought-pattern, science emerged as the most prominent force responsible for making this modern world so startlingly different from all preceding ages. Thus when, for many people, the modern world, in spite of all its resources, began to slip from its role of "best of all imaginable worlds," science came in for a proportionate share of blame.

Had a more accurate picture of the part science has played been presented, science would not now be the object of so much suspicion and resentment.

It is true that the modern world is a product of science, but it is also a product of the commercial and industrial expansion which seems to have had its inception in the city-states of northern Italy about the fifteenth century. Only by distorting the meaning of science to be synonymous with all types of initiative and daring having an intellectual content, can this expansion be regarded as a phase of scientific activity. This economic expansion and the rise of scientific inquiry are more properly to be interpreted as separate aspects of the more general cultural renaissance.

It is true that, in technology, industry and science have cooperated to a large extent. But for *pure* science, facts and laws have their gradations of importance regardless of whether or not they have immediate application. The criteria here are the fundamental nature of the facts, and the generality of the laws, as they bear on a fuller understanding of nature. Admittedly, the scientist, in mapping out his programs of research, is not always oblivious of the ultimate utility of his possible findings. But his immediate, and primary objective is to uncover more elements of behavior in

nature, and to correlate these elements under a general principle or theory.

The inventor or technologist, on the other hand, is not concerned with facts, old or new, which do not contribute directly to the perfection of the device or method upon which he is working. It may be said that, in general, it is only the technique of experimentation that the inventor has in common with the scientist. Many early inventors not merely ignored, but actually defied, the accepted scientific doctrines of their time, and evidently with success.

Still another agency, distinct from either science or invention, has contributed to the material comfort and convenience of modern life. It is the spirit of initiative and adventure without which, though we still had our science, the world would be very different. It is this spirit which has thrown great bridges across rivers, railroads across continents, airways and cables across oceans, given us by mass production, automobiles, electric refrigerators, radio receivers and the host of other accessories of present-day life. It is this same spirit which leads to competition and friction between groups of people, within borders and across borders.

Thus, a more comprehensive view discloses that science was not the main spring in the development of our modern material facilities, but rather, one of several contributing factors. The role of science was passive; it made available facts and laws which men of action in time saw fit to exploit advantageously. Condemnation of science for the present social and economic derangement of the world is as unwarranted as was the undivided credit it received in earlier, more prosperous decades.

III

What attitude scientists are to adopt toward those political regimes which are unfavorable, if not outright antagonistic, to scientific progress, already appears to have become a matter for debate.[5] At the outset of any discussion of this type it should be emphasized that scientific groups have no business taking up the torch for any political or religious "ideologies," however attractive some of these, or abhorrent others, may be to the individual scientist personally.

Those of us adhering to the liberal tradition should like to identify pure science with democracy on the theory that, in the realm of ideas, science stands, as does democracy in the social domain, against authoritarianism. We note that in both modern science and ideal democracy, the statement or conclusion of no man is beyond criticism or scrutiny; that in science a great principle is never irrevocably established, but is accepted only in so far as it is in accord with a wide array of experimental facts, just as in a republic, a government and its laws exist only so long as they are in accord with the will of the popular majority. But, however attractive this analogy may appear, as with all analogies, it can not be pushed too far, to be confused with an identity. That the positions of science and democracy are merely analogous, and that the two not always have been even allies and sole mutual supporters, is indicated by the disinterested prospect of history. We have only to recall the brilliant researches of the French mathematical physicists of the eighteenth century, whose work was supported by the aristocracy of a decaying despotism. Again, no one can say that pure science did not thrive in imperial Germany. On the other hand, we recall that the first truly popular, democratic movement in Europe found "no use for scientists," and forthwith beheaded the father of modern chemistry.

[5] The principle involved here has been analyzed by D. C. Smith, *American Scholar*, autumn, 1937.

Science can not endorse this or that ideology, or social system simply because, as has been often pointed out, science can not choose between objectives or ultimate values. Any such an alignment is artificial. It does not appear, however, that scientists must remain oblivious of current social and political developments having implications in the activities of science.

Science has a job to do: to enlarge man's knowledge of nature and of the world in which he lives. The materials of science are facts. Its method is not to stop at arbitrarily established boundaries, if beyond may lie truths to be uncovered and examined. And because this method is of the essence of modern scientific inquiry, scientists have the right to insist that the integrity of the method be preserved. The public proscription by scientific organizations of those agencies or régimes which endeavor, by coercion, if not by law, to circumscribe the activities of science, to supplant objective data with propaganda, or to circulate flimsy, immature opinion as scientific doctrine, can not be declared inappropriate. Thus, the recent indictment by a group of American anthropologists of the National Socialist doctrine of "Aryan" supremacy, as having no factual basis, was a commendable move.

In general, toward recent ideological developments the attitudes of scientists thus far appear to be divided. Some scientific workers are inclined to remain aloof and complacent, concerning themselves with the solution of their immediate technical problems. Their view, evidently, is that the infringement on free inquiry by political and religious ideologies is not something "new under the sun," and that it has not in the past proved fatal. With that view goes the conviction that the very accomplishments of science make its acceptance and support inevitable. The spirit of this group, it would appear, dominates the scientific societies and accounts for the extensive silence of the latter in the face of current developments.

Scientists of another temper, alarmed at the prospect of a worldwide censorship of research and inquiry, and being unable to register their apprehension and disapproval as a scientific body, have aligned themselves with pro-liberal organizations whose objectivity is questionable. Neither one of these courses is highly effective in preserving a progressive, untrammelled science, free from potentially discrediting alliances.

While the sense of the complacent scientist may be justified, I propose that he re-examine his premises, bearing in mind that earlier successful cultures, becoming assured and complacent, have been supplanted. And not always has the new order been superior; one civilization at least, that of Rome, disappeared in the darkest barbarism. It is not advocated that scientists organize to entrench modern science as an established system, simply for the sake of self-perpetuation. Indeed, if it is conceivable that some method of inquiry other than the one we now know as the *scientific*, could more readily give man an accurate picture of his world, scientists should be the first to welcome the method. The real problem is the preservation of a proven method of inquiry against the suppression of all significant inquiry.

THE SOCIAL SIGNIFICANCE OF SCIENCE

By HENRY M. WRISTON

PRESIDENT OF BROWN UNIVERSITY

THERE is no question whatever that the advance of science has the deepest social significance; it is manifested dramatically in the triumphs of medicine, in the triumphs of the battlefield and in the triumphs of plenty through an economy of abundance. But I need not, in this tragic hour, remind you that each song of triumph has its antiphonal song of despair. For science is being used to destroy more men than the science of medicine can save, and triumph in war is defeat both for victor and for vanquished. Even as men fight for victory they know the losses will be awful. The economics of plenty subsists in a world where politics decrees an economics of scarcity. In fact, political forces have overcome scientific forces until millions of men are unemployed; plenty is burdened with taxes for the support of scarcity, and abundance is destroyed for the sake of power. "Guns before butter" is only the most conspicuous illustration. Meanwhile medicine is used to heal the artificial wounds by which we supplement the ravages of nature.

Under ordinary circumstances the call for an interpretation of the social significance of science might be taken as a somewhat wishful, not to say nebulous, observation. At the moment, however, there is a hard reality which gives it point. The university, the home of pure science, and industry, the home of applied science, have both been hard hit. The partial devaluation of the dollar, which operates over the long pull substantially as a capital levy, and the artificially low interest rates produced by political manipulation of credit for the benefit of perpetually unbalanced governmental budgets are two of many adverse influences. In Germany inflation was carried so far that endowments were wiped out, and science, already too heavily controlled by the government, was thrown entirely into the hands of the state. The universities of England to-day face the fact that they are virtually mobilized for war purposes; they are in the hands of the state. If the war be long and costly, as it appears likely to be, then their independent resources will be impaired or destroyed. The state may not be willing to allow them the freedom they have heretofore enjoyed, because social pressure for immediate utilities and services will run adversely to the support of pure science. Without pure science as its refreshing well-spring, applied science must soon suffer.

Whether the United States stays out of the war or goes into the war, this nation will be impoverished. The profits of neutrality in modern war are illusory. Even if we remain neutral, the costs of armament in the United States will mount beyond all previous expectations; the costs of living will go up; our currency may come to be, in the technical phrase, "overvalued" with reference to the currency of warring nations; our debts will be so large that the government will not want to pay them. It is the characteristic history of government debts, just as of private debts, that when they are too large they are not paid. Witness the German reparations, witness the inter-allied debts, and, if you please, witness the devaluation of the American dollar. If our currency is overvalued in that technical sense and if the debt

gets too large, it means a further devaluation of the dollar, a further capital levy, that is to say, upon endowed funds and upon industry. That, of course, would involve a corresponding dependence of pure science upon the state, and a further diminution of corporate profits resulting in restricted budgets for applied science. The necessity, therefore, of an acute awareness of the social implications of science, of the impact of science upon social organization and the social future is instant and immediate, not only for the benefit of society as a whole, but for the benefit of science itself.

In Washington the Senate has been engaged in a widely advertised debate upon neutrality. Like most discussions it wandered from the real issue to deal with many other points. Certainly the disputants had security more actively in mind than neutrality. But the neutrality of politics is always imperfect at best, while the neutrality of science is absolute. Science made possible the conquest of the air, but that conquest can be used for carrying bombs or for carrying the mails. Science with even hand provides poison gas and the means to defeat it. Science impartially devises high explosives and the armor to resist them. Science provides the instruments to wound men and to cure them. In the great warfare between good and evil, therefore, science is of necessity neutral; but it is not necessary that the scientist be neutral. The chemicals, the energies, the instrumentalities of science must be oblivious to values, but the men who employ them can not be, for scientists must be men before they can be scientists, and their humanity must be greater than their skill.

The other day I was visited by a man who has had a distinguished record in one of the fields of engineering and also as a political and diplomatic adviser. He was lamenting the fact that in the universities it was almost impossible to find a man dealing with the great problems of international relations who had any understanding whatever of the impact of science and technology upon the life of the world, who had any conception at all of the importance of science to our outlook upon individual life and death and our view-point upon national political and economic life. He went on equally to lament that among scientists there was a similar want of understanding of the social significance of their own labors and of the rôle which their skills might play in the reorientation of international affairs.

Research has achieved many of its distinctive triumphs at the cost of loss of perspective; men of learning have rent the seamless fabric of life in order that each might fashion his own banners. However gaily those banners may flash in the sunshine and however proudly they may be carried at the head of triumphant advances, we may be reminded in the current tragedy of the world that such triumphs can be hollow. The achievements can be rendered nugatory. The advances may be halted. Indeed, we may be thrown back into black darkness unless men of science understand the social significance of their work and are activated by the warm emotions of the humanities, unless those who give their lives to the study of society are ready also to take full cognizance of scientific progress, and unless the philosopher whose duty it is to embrace all knowledge and to bring it into coherence and significance can unite with the scientist and the social student in this major enterprise of common understanding.

There have been fantastic proposals for various "courts of wisdom" composed of leading men in the several fields. At the moment they would have no effective means of talking with each other, since they do not understand each other's language. Consequently, these would be

courts of foolishness rather than of wisdom, for they would have to seek the greatest common divisor in their intercourse, and that common divisor would be pitifully small. The one solution is synthesis, and synthesis can occur only in the mind of one man at a time. If anything like the same portion of energy were turned toward this synthesis as was put into the attempt to find an equation which united matter and motion, time and space, we should have results, if not as startling, at least as useful and promising.

MEDICINE IN THE BIBLE*

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THE Bible has been variously regarded as a text-book of theology, a source book of sermons and a reference book of early Jewish and Christian church history. But no one can overlook the fact that it is a great work of literature, a document full of vital and varied human interest. To those who are interested in preventive medicine and hygiene, it affords entertaining reading. As we browse through its pages, we are struck by the fact that the one person who must be regarded as the founder of this science is none other than Moses. Stripped of the mythology and legends which surround his life, Moses still stands out as a colossal personality, a brilliant legislator, an inspired and inspiring teacher, a righteous judge, an able executive and an efficient sanitarian. It was he who organized the first department of health in the history of the world.

While it is possible that Moses learned his medical lore from the Egyptians, it is nevertheless conceded that he synthesized this knowledge into a philosophy of life and into a religion. He advanced the practice of personal and public hygiene, not as a taboo, but by appealing to the religious emotions and to a sense of the nobility of life. To quote Leviticus 19: 2, "Ye shall be holy, for I the Lord, your God, am holy." Likewise in Deuteronomy 23: 15, we read, "for the Lord thy God walketh in the midst of thy camp,—therefore shall thy camp be holy; that He see no unseemly thing in thee, and turn away from thee." Freedom from disease was the reward offered in return for obedience to the will of God. "If thou wilt diligently hearken to the voice of the Lord thy God, and wilt do that which is right in His eyes, and wilt give ear to His commandments, and keep all His statutes, I will put none of the diseases upon thee, which I have put upon the Egyptians: for I am the Lord that healeth thee."[1]

In order to appreciate the full significance of the hygienic laws of Moses, it must be recalled that he was leading a people just liberated from Egyptian bondage, through a great wilderness, a desert land devoid of all sanitary facilities. This undisciplined army had to be maintained in good physical, mental and spiritual health. To begin with, there was the task of providing potable drinking water and wholesome food. This meant provision for the disposal of refuse and excreta, of dead human and animal bodies and the development of a system of control of communicable diseases. Any one familiar with military science and tactics knows that even to-

* Address delivered at Stanford University (Bible Exhibit Dep't of Classics) April 14, 1937, and in the Hall of Religion, Golden Gate International Exhibit, June, 1939.

[1] Exodus 15: 26.

day this is a gigantic task, both during war and peace.

Let us see how Moses accomplished this. First, he protected the water supply. "This is the law: when a man dieth in a tent, everyone that cometh into the tent, and everything that is in the tent, shall be unclean seven days. And every open vessel, which hath no covering closebound upon it, is unclean."[2] When a diseased animal fell into an open vessel, it was considered unclean and unfit for use. Hence we read in Leviticus 11: 33, 'And every earthen vessel, whereinto any of them (dead animals) falleth, whatsoever is in it shall be unclean, and it ye shall break." By preventing contamination of drinking water, many intestinal diseases were avoided. Among these are typhoid fever as well as bacillary and amoebic dysentery.

When we recall the absence of facilities for refrigeration and sterilization of food during Biblical times, we must regard the dietary laws instituted by Moses as nothing less than life-saving. Many of the land and water creatures whose food he prohibited were either commonly infected or subject to infestation. Animals known to be diseased were forbidden as food. An animal which had been partly devoured by another was "unclean." Such animals may have become infected with rabies or hydrophobia. The pig is frequently infested with flukes, trichina or with pork tapeworm. Rabbits may be infected with a disease known as tularemia. Shell fish are frequently contaminated with human sewage and typhoid bacilli. Schistosomiasis is carried by some species of snails. Wild animals often die of plague or tuberculosis. All these were placed on the forbidden list, thus avoiding epidemics of food infection and food poisoning.

Another remarkable chapter in the sanitary code of Moses deals with the disposal of human refuse. We read in Deuteronomy 23: 13 and 14, "Thou shalt have a place also without the camp, whither thou shalt go forth abroad. And thou shalt have a paddle among thy weapons; and it shall be, when thou sittest down abroad, thou shalt dig therewith, and shalt turn back and cover that which cometh from thee." The late Major O'Connor, who was with the British army when General Allenby entered victoriously into Palestine, informed me that this is essentially the method used by the British soldiers during the recent World War. Its effect was to prevent infestation of soil and water with hook-worm and schistosomiasis,—Bilharziosis, a disease known to the ancient Egyptians, and still common to-day in tropical and semi-tropical countries.

When one reads in the pages of European history that as late as the seventeenth century creams, perfumes and powders were used in the place of bathing, the value of the ritual baths, mentioned in the Bible, may be more fully appreciated. There were so many instances when a person had to take a bath or wash his hands for religious reasons that the practice became very common. Thus in Leviticus and Numbers we find the following regulations regarding bathing: (1) Any person who came in contact with the body of, or with the articles of furniture used by, a person having an unclean issue (venereal disease), or with any article used by him was obliged to wash his body and his garments.[3] Washing of clothes was required after touching the carcass of a beast that had died of a natural death.[4] (2) Bathing was required after sexual intercourse[5] or after touching a woman who was menstruating. Whoever had come in contact with a corpse or a grave was unclean and

[2] Leviticus 11: 32; Numbers 19: 14 and 16.

[3] Leviticus 15: 5–10.

[4] Leviticus 11: 25 and 40.

[5] Leviticus 15: 18 and Second Samuel 11: 4.

had to bathe.[6] When a "leper" was "healed" of his leprosy, he shaved off his hair, washed his clothing and bathed his body in water.[7] The following reference in the New Testament is of interest in this connection, "For the Pharisees, and all the Jews, except they wash their hands oft, eat not, holding the tradition of the elders."[8]

The efficacy of mineral baths is recorded in the Bible. The saline waters of the Jordan, the pool of Siloam, as well as the waters of the Bethesda, became famous for their healing powers.

While we do not wish to suggest that Moses had any knowledge of bacteria or parasites, he must have arrived, intuitively or empirically, at the mode of spread of contagious diseases. For after the war with Midianites, he commanded, "whosoever hath touched any slain, purify yourselves on the third day and on the seventh day, ye and your captives. And as to every garment, and all that is made of skin, and all work of goat's hair, and all things made of wood, ye shall purify." "Howbeit the gold, and the silver, the brass, the iron, the tin, and the lead, everything that may abide the fire, ye shall make to go through the fire, and it shall be clean; and all that abideth not the fire ye shall make to go through the water." "And ye shall wash your clothes on the seventh day, and ye shall be clean, and afterward ye may come into the camp."[9]

One of the most remarkable public health procedures given by Moses related to the isolation of persons infected with communicable diseases. This routine applied not only to persons afflicted with a venereal disease (gonorrhea), but to that group of skin infections known in Hebrew as "Zoraath" and loosely translated as "leprosy." It is noteworthy that not only the patient himself was to be quarantined, but even those that had had contact with him. "What man soever of the seed of Aaron is a leper, or hath an issue, he shall not eat of the holy things, until he be clean. And whoso toucheth any one that is unclean by the dead; or from whomsoever the flow of seed goeth out; or whosoever toucheth any swarming thing, whereby he may be made unclean, or a man of whom he may take uncleanness, whatsoever uncleanness he hath; the soul that toucheth any such shall be unclean until the even, and shall not eat of the holy things, unless he bathe his flesh in water. And when the sun is down, he shall be clean; and afterward he may eat the holy things, because it is his bread. That which dieth of itself, or is torn of beasts, he shall not eat to defile himself therewith: I am the Lord."[10] "And he that is to be cleansed shall wash his clothes, and shave off all his hair, and bathe himself in water, and he shall be clean; and after that he may come into the camp, but shall dwell outside his tent seven days. And it shall be on the seventh day, that he shall shave all his hair off his head and his beard and his eyebrows, even all hair he shall shave off; and he shall wash his clothes, and he shall bathe his flesh in water, and he shall be clean."[11]

One of the most remarkable achievements in the field of preventive medicine and hygiene is the introduction by Moses of a compulsory weekly day of rest (the Sabbath) for *all* the people. It is true that the ancient Babylonian calendar included certain days when the king could not perform certain functions; such as riding in a chariot, using fire or wearing the robes of his kingdom. A weekly day of rest for *all the people*, however, is indeed a step forward in democracy, as well as in physical and mental hygiene.

[6] Leviticus 11: 25 and 40.
[7] Leviticus 22: 4 to 6.
[8] St. Mark 7: 3.
[9] Numbers 31: 19–24.
[10] Leviticus 22: 4–8 inclusive.
[11] Leviticus 14: 8 and 9.

The Jewish and Christian peoples were the first to benefit from this Mosaic law.

Medicine and Surgery in Biblical Times

While the Bible is not to be regarded as a text-book of the practice of medicine, nevertheless we may glean from its pages much interesting information in this field. Thus, the art and the science of obstetrics were fairly well developed, as shown by frequent reference to the employment of skilled midwives and to the use of the birth-stool.[12] Various anatomical anomalies are described in connection with the laws governing the priesthood and marriage.[13] Priests had to be free from certain defects in order to be permitted to carry on their sacred functions.[14] Women were ineligible for marriage for analogous reasons. Animals could not be brought to the altar as a sacrifice if they suffered from any one of a variety of pathological conditions.

Scattered here and there we find other fragments of medical knowledge. Many diseases were known and described. Among them are affections of the nervous system, the heart and blood vessels, infections of the eye and skin, tuberculosis of the lungs and of the spine, tumors, hemorrhoids, erysipelas and a variety of fevers and boils.[15] Several mental diseases are recorded with great vividness and accuracy. Thus, King Saul suffered from recurrent paroxysmal mania (insanity). King Saul was a naturally self-conscious man, easily exalted into ecstasy and tyrannical self-satisfaction. He was possessed of homicidal tendencies, turned against his own son and finally becoming despondent, he met with death by suicide. Nebuchadnezzar suffered for seven years from a type of monomania (mental derangement) which caused him to believe himself to be a beast.

Epilepsy is referred to repeatedly in the Bible. The most accurate description is in the Book of Saint Luke 9: 39. "And, lo, a spirit taketh him, and he suddenly crieth out; and it teareth him that he foameth again, and bruising him hardly, departeth from him."[16]

A variety of "palsies" are mentioned. Some of these may well have been due to infantile paralysis. As in Saint Matthew 8: 5 and 6, "And when Jesus was entered into Capernaum, there came unto him a centurion, beseeching him, and saying, Lord, my servant lieth at home sick of the palsy, grievously tormented." In Saint Matthew 12: 10–23 we read, "And, behold, there was a man which had his hand withered."[17]

A stroke of apoplexy resulting from heart disease is described in I Samuel 25: 37 and 38. Nabal, after a hearty supper and somewhat riotous night, was stricken with apoplexy and died ten days later. As stated, "His heart died within him, and he became as a stone. And it came to pass about ten days after, that the Lord smote Nabal, that he died."

It is probable that the so-called Biblical "canker" is identical with the modern word cancer. Thus we find in Second Timothy 2: 16, "And their word will eat as doth a canker."

A number of infectious diseases are mentioned. Among them are gonorrhoea and what is probably bubonic plague (the burning boil).[18] This may possibly be the so-called "Damascus boil," a form of leishmaniasis. In Deuteronomy 28: 22 we have reference to fevers which are probably of malarial origin and to consumption which may be identical with pulmonary tuberculosis. "The Lord shall smite thee with a consumption, and

[12] Exodus 1: 16.
[13] Deuteronomy 23: 2.
[14] Leviticus 21: 18–21.
[15] Deuteronomy 28: 15, 22, 27 and 28.
[16] See also St. Matthew 17: 14–18.
[17] See also The Acts 9: 33–34.
[18] Leviticus 13: 23.

with a fever, and with an inflammation, and with an extreme burning, and with the sword, and with blasting, and with mildew; and they shall pursue thee until thou perish." Evidence of a knowledge of tuberculosis of the bone is suggested by the law that a priest who had contracted spinal caries could not minister in the sanctuary.

As is still true in the Orient of to-day, diseases of the eye were especially prevalent in Biblical times. We read in Genesis 29: 17, "And Leah's eyes were weak; but Rachel was of beautiful form and fair to look upon." Scholars have concluded that Leah suffered from trachoma, which led to continuous weeping.

At the head of the list of surgical procedures mentioned in the Bible is circumcision,—a ritual which has survived among the Jewish people unto this day.[19] The prophylactic value of this operation may be deduced from a recent article in the London *Lancet* by Dr. Wolbart. He points out that cancer of the male organ constitutes 2 to 3 per cent. of all types of this disease in man. In the Far East it rises to about 15 per cent. A careful examination of 205 American hospitals by six individual observers showed that of 1103 cases of cancer of the male organ, there was not a single Jew. Likewise 26 Jewish hospitals did not report a single case in a Jew. Jews circumcised during infancy (usually on the eighth day) do not develop cancer. Cancer of the penis does occur rarely in Mohammedans who practice ritual circumcision between the fourth and ninth year. According to an editorial in the *Lancet*,[20] the annual mortality from this type of cancer in the United States is about 225. Most of these can be prevented by circumcision in early life.

Circumcision was not the only operation practiced in Biblical times. A number of surgical instruments are mentioned, including sharp cutting stones, knives and awls. The Book of Ezekiel, 30: 21, refers to the use of a roller bandage to mend a broken limb, "Son of man, I have broken the arm of the Pharaoh, king of Egypt; and, lo, it hath not been bound up to be healed, to put a roller, that it be bound up and wax strong, that it hold the sword."

From casual references we conclude that the pharmacist, or apothecary, was well established in his profession in Biblical times. Thus in Ecclesiastes 10: 1, we find, "Dead flies make the ointment of the perfumer fetid and putrid; so doth a little folly outweigh wisdom and honour." Mention is also made of the merchant in powders, which shows that medicines had become important articles of trade.[21] Among the medicines employed were the balm of Gilead, myrrh, cinnamon, cassia, aloes, calamus, camphor, mandrake and stikenard. Oil and wine were also poured upon wounds, as in the story of the good Samaritan.

Music as a form of treatment for those afflicted with mental disease is described in Samuel 16: 14 and 23, "Now the spirit of the Lord had departed from Saul, and an evil spirit from the Lord terrified him." "And it came to pass, when the evil spirit from God was upon Saul, that David took the harp, and played with his hand; so Saul found relief, and it was well with him, and the evil spirit departed from him."

Among the ancient Israelites, unlike other primitive peoples, the priests did not monopolize the art and science of healing. Moses assigned to them only the task of supervision in cases of contagious diseases. The Bible does not mention a single instance of a priest having performed the function of a physician. The prophets, however, practiced occasionally the art of healing. Thus, Elijah brought to life a child apparently

[19] Exodus 4: 25.

[20] *Lancet*, 1: 39, 1927.

[21] Song of Songs 3: 6.

dead.[22] His disciple Elisha performed a similar miraculous cure.[23] A man of God restored the paralyzed hand of King Jeroboam.[24] Isaiah cured King Hezekiah of an inflammation by applying a poultice made of figs.[25] "In those days was Hezekiah sick unto death. And Isaiah the prophet the son of Amoz came to him and said unto him: Set thy house in order; for thou shalt die, and not live." "And Isaiah said: 'Take a cake of figs.' And they took and laid it on the boil, and he recovered."

In the New Testament we have repeated reference to Saint Luke, "the beloved physician" who practiced at Antioch.[26] The medicine practiced by St. Luke was, no doubt, influenced by the contemporary Greek civilization.

When we come down to the time of the Apocrypha, we find an increased regard for the distinct profession of medicine. Thus we read in II Chronicles 16: 12, "And in the thirty and ninth year of his reign Asa was diseased in his feet; his disease was exceedingly great; yet in his disease he sought not to the Lord, but to the physicians."

In Ecclesiasticus there is repeated mention of the physician. In chapter 38 we find the following famous quotation (The Wisdom of Jesus the Son of Sirach), "Honor a physician with the honor due unto him, for the uses which ye may have of him; for the Lord hath created him. For of the most High cometh healing and he shall receive honor of the King. The skill of the physician shall lift up his head: And in the sight of great men he shall be in admiration. The Lord hath created medicine out of the earth, and he that is wise will not abhor them."

"Give place to the physician for the Lord hath created him. Let him not go from thee, for thou hast need of him. There is a time when in their hand there is good success."

[22] I Kings 17: 17–22.
[23] II Kings 4: 18 and 34–55.
[24] I Kings 13: 4–6.
[25] II Kings 20: 1 and 7.
[26] Colossians 4: 14.

BOOKS ON SCIENCE FOR LAYMEN

SOME PIONEER PSYCHOLOGISTS[1]

If any one doubts the existence of a wide-spread interest in the topic of the "mind," let him glance over the array of brightly colored "pulp" magazines on the corner news-stand and note with amazement the large number dealing (allegedly) with psychology and cognate topics. To be sure, they are filled largely with twaddle or worse, but they sell, and that is all the publishers ask. This is merely a roundabout way of saying that many people are interested in mental phenomena, their nature and laws. Most readers of this journal, too, are interested in knowing something of the development of sciences and of the men who brought about advances in scientific thought. We sometimes forget that advances, whether in science or government or any other field of human endeavor, do not "just happen" or take place automatically; they are due, rather, to the genius or keen observation or hard work of men and women, people who have built additions to a superstructure erected upon the foundations laid by those thinkers who have gone before.

In this volume we have a sprightly account of the lives of men who have added to the sum total of human knowledge regarding mental functioning and the care of the mentally disordered. Mr. Winkler is a competent biographer, who writes in a highly entertaining, though far from lurid, manner; Dr. Bromberg, the author of "The Mind of Man," is an able psychiatrist who is not only a careful student but is himself possessed of a pleasing literary style. Thus we have presented readable and accurate biographical sketches of about twenty men who have made valuable contributions to the study of the mind. We find presented unfamiliar and familiar facts of the life and work of such men as Gall, the phrenologist, an unwitting founder of the science of neurology; Mesmer, who emphasized the value of suggestion in psychotherapy; Pinel, who struck the shackles from the unfortunate inmates of the Bicêtre and thus established non-restraint as a principle in the care of the mentally ill; Galton, the founder of biometrics; William James and G. Stanley Hall, the fathers of psychology in America; Watson, the behaviorist; Terman, the psychometrician; Beers, the founder of the mental hygiene movement; Adolf Meyer, the dean of American psychiatrists; J. McKeen Cattell, the founder not only of *Science* but of experimental psychology in this country; and Freud, who will probably go down in history as the greatest giant of them all.

The book is heartily recommended to all who are interested in psychiatry and psychology; to those who have an intelligent interest in the care of the mentally ill; to those who rejoice in the accomplishments of original thinkers; in short, to all who boast of a functioning forebrain.

WINFRED OVERHOLSER, M.D.

[1] *Mind Explorers.* By John K. Winkler and Walter Bromberg, M.D. 378 pp. $3.00. Reynal and Hitchcock. 1939.

FROM THE DAWN OF SURGERY[1]

THE story of surgery and of surgeons is a brilliant and fascinating tale of human progress in a field beset by obstacles and inertia of precedent, obstinacy and prejudice born of ignorance. Hiding behind the nom de plume of "Harvey Graham," a prominent British physician feels free to tell his story without cumbersome documentation, dates and footnotes and to interpose his own critical evaluations of men, manner and thought. The style is admirable, and the author obviously has a wide and accurate knowledge of his subject. From early

[1] *The Story of Surgery.* By Harvey Graham. Illustrated. xv + 425 pp. $3.00. Doubleday, Doran and Company, Inc. 1939.

demonology, tribal ritual and witchcraft to modern surgery, the story unfolds itself by excellent biographic pictures of the great men who carried forward the torch of scientific reason and logic: Asklepios, Hippocrates, Galen, Paré, Harvey, Liston, Syme, Lister and many more. There is a disproportionate emphasis of British contributors to progress, but the charm of these word pictures so far exceeds the usual biographic sketches in more "formal" histories that one forgives the unilateral view-point.

The author's personal comments and philosophy are absorbingly stimulating. One reads for pleasure, becomes absorbed and suddenly realizes how much understanding one has acquired en route. In discussing the dim dawn of surgery in certain tribal customs, "Graham" comments as follows: "The origin of even the most primitive operation lies in reason. The reason may be inaccurate, but there always is a reason." One pauses to reexamine some of our own scientific concepts.

This is a volume which should and will interest the layman even more than the physician or surgeon. Devoid of technicalities and written in a lively personal style, it is an accurate history of surgery and of its sociologic implications from the Stone Age to the present day. Viewed in this perspective, the forecast of the future of surgery is provocatively stimulating.

EDWARD J. STIEGLITZ

TO FIND A SNAKE[1]

THIS is a simplified handbook for the identification of the snakes to be found in the United States, east of the Rocky Mountains. When the authors of a book of this type have a systematic knowledge of their subject, they have a more difficult task in the simplification of their subject than with straight scientific writing. Translation of such a subject to the terms that may be clearly understood by the layman is always done with a feeling that much is being left out, but this book represents an excellent job of what can be done along these lines.

In the first place, the authors have taken the continental map east of the Rockies and divided it into six areas. It is explained in a caption of a full-page map so divided: "The first step in the identification of any snake is to determine the Area in which it was found. Then look it up in the Key, under the proper Area number."

The "Identification Key" is of an entirely original character, as keys appear nowadays—and some are of bewildering complexity. This is the simplest kind of key, but that does not mean that it was easy to prepare. This reviewer will wager that the authors of the handbook spent more time and thought in the simplification of the key than one with many indentures or cross references by numbers. The key forms a separate chapter of seven pages, based upon continental areas designated by numbers for cross-reference to a map, with subdivisions as to scales being smooth or keeled and the anal plate single or divided. Within the subdivisions are lists of the species, with brief annotations as to pattern and reference to page description and plate number if the species is illustrated.

Descriptions are satisfactorily presented and the strictly up-to-date nomenclature shows all care in the consideration of various forms appearing in the latest formal lists, which have been undergoing considerable changes. Descriptions are accompanied by readable outlines of habits.

RAYMOND L. DITMARS

IN THE TIDAL ZONES[1]

THIS book is intended to be equally useful to both the scientist and the lay-

[1] *What Snake is That?* By Roger Conant and William Bridges. 163 pages. 108 drawings. $2. D. Appleton-Century Company. 1939.

[1] *Between Pacific Tides.* By Edward F. Ricketts and Jack Calvin. $6.00. 320 pp., 112 figs., 46 plates. Stanford University Press. 1939.

man. Because the order in which the animals are listed is according to habitat, and since both the binomial and common names have been used, the authors have met with a high degree of success in attaining their objective. As the senior author has had many years of experience in collecting, the animals have been well chosen with regard to their abundance. One will seldom find an animal of the tidal zones which has not been included in the book.

An appendix listing the binomial of all the animals included in the book, and arranged according to phyla, classes and orders, will be found on pp. 257–302. Immediately following each binomial within this list the authors have given references to papers dealing with each particular animal; and they have also included a general bibliography on pp. 302–306. The entire bibliography lists some four hundred references.

The arrangement of the book is unique in that it is divided into four main divisions which refer to particular habitats, namely: 1, "Protected Outer Coast"; 2, "Open Coast"; 3, "Bay and Estuary"; and 4, "Wharf Piling." These regions are again subdivided. For example, the "Protected Outer Coast" is divided into "Rocky Shores" and "Sandy Beaches," and these in turn are divided into four zones: "Upper," "High Tide," "Mid Tide" and "Low Tide." The advantages of such a plan are readily evident. If one wishes to look for a certain animal or animals, reference to the appendix and then to that part of the book dealing with the region one expects to visit will supply one with the necessary information. From the other point of view, if one has been collecting and wishes to classify his catch, reference to that part of the book dealing with the habitat visited will supply the desired names. Since practically every animal is illustrated either by figure or photograph, the classification is greatly facilitated and made doubly certain of being correct. However, a strictly technical classification is outside the scope of such a book, but it can be pursued through reference to the bibliography.

An interesting and exceedingly valuable feature of the book is the inclusion of reliable natural history information about each species when such information was available.

"Between Pacific Tides" is a well-written, informative treatise on 570 marine animals of the Pacific Coast, together with data on their environment and natural history. It well deserves a place on the reference shelf of every educational institution of the Pacific Coast as well as of every zoological library.

G. E. MacGinitie

A NATION-WIDE INSTITUTION[1]

THERE appears in the foreword, "These volumes record an effort to see museums as a whole, the institution in different patterns, the work it does, the people who give it life—all in the matrix of society. The book is not a manual, but a commentary on the condition, the strengths and weaknesses, and the limitations and opportunities of museums.

"In sketching familiar conditions, I have gone beyond recounting briefly what everybody knows by saying what I think about what everybody knows. . . . Parts One and Two hew close to the line in locating, counting, measuring, and describing the museums of the country. . . . Part Three—on museum work—allows some latitude to the reporter, and here the larger institutions get most attention because they are most active. . . ."

[1] *The Museum in America.* By Laurence Vail Coleman. $7.50. Three volumes. viii + 218 pp., xiii + 428 pp., xviii + 730 pp. Illustrated. American Association of Museums, Washington, D. C. 1939.

The author has visited nearly all the museums in America, and seemingly he has studied all the historical data. The historical and statistical facts have been well digested and well arranged, and the writing should be attractive to those who have professional interest in the museum.

Of the public museums, 224 are of art, 358 of history, 60 are general museums, 8 are of "industry and the like," and 72 of science.

This review will concern itself mainly with the last two groups. The Museums of Science and Industry in New York and Chicago and the Franklin Museum in Philadelphia receive major treatment. The author objects to the name "Science and Industry." To quote: "The worst trouble about the term 'science and industry' is its implication that two fields are covered. Science has come to mean pure science. . . . Although pure science is not in the province of industry museums as a rule, there are a few exhibits on the principle of science by way of introduction to exhibits showing how they are applied. . . . Also, they are not much concerned with the increase of knowledge through investigation. They project no research functions like those of other museums. To take up this work would be to back away from the social aim and to approach industrial services in the realm of invention and management."

This type of museum is relatively new, and it is therefore about as futile to predict its character as it is for an uncle or even a father to predict the outcome of a child. Not long ago the president of a great university stated that one of his institutions would not do research work because it was written in the code. Nevertheless, the institution is doing research work. Pure science is basic to modern industry. It is unthinkable that the museum can rise to broad esteem without depicting pure science. Seemingly the author is unaware that such depiction is already in process. Just as universities learned that research was vital, even so these new museums must and do recognize that the search for new knowledge is as important as proper display.

The author, however, does recognize the places of research in museums such as the Field Museum and the American Museum of Natural History. It is only fair to quote him. "Like institutions of higher education, museums are likely to be as deep or as shallow in their teaching as they are strong or weak in research. Where there is no spirit of inquiry, there can be but limited learning since the scholar is a product of the habit of investigation. Where teaching goes on unrefreshed by learning, it soon becomes uninformed and even sooner dull. . . . But the present danger in most places is from too little, not too much, research work." These expressions make it the more incomprehensible that the author fails to recognize the essential place of research in the museums of science and industry.

Thus in expressing his views about "what everybody knows" the author has set himself as a philosopher, but in so doing has in some cases already notably erred by using wrong postulates, inaccurate or superficial observation, and illogical deductions. He has implied that attendance records are not a basis for measuring the effectiveness of a public museum as an education institution. It would seem to the reviewer that in the long run, attendance multiplied by visitors' capability factor is the only safe basis for estimating effectiveness. On this basis published researches, books, magazine and news articles, lectures, as well as comprehensive exhibits, will be reflected in the number and quality of the visitors.

F. C. Brown

E. O. LAWRENCE

THE PROGRESS OF SCIENCE

NOBEL PRIZE AWARD IN PHYSICS FOR 1939 TO E. O. LAWRENCE

DURING the past twenty years five Americans have been recipients of the Nobel prize in physics, while during the first half of the period for which these awards have been made, only one, Professor A. A. Michelson, was so distinguished. This is another evidence of the remarkable development of physics in this country since the World War. Sometimes considered to be part of the aftermath of that war, sometimes associated with the establishment of the National Research Fellowships in physics, this transformation of American physics from an offshoot of European science to a position of independence and leadership has been gratifying to all those concerned in it.

The latest recipient of this high distinction is Professor Ernest O. Lawrence, of the University of California. Born in South Dakota, his formal education obtained in American universities, he serves as a representative example of an American physicist. His leadership in the field of nuclear physics has been recognized all over the world since his development of the cyclotron has made the Radiation Laboratory at Berkeley the Mecca of those engaged in this type of work.

Achievements in atomic and nuclear physics have been made possible through the development of methods for producing large concentrations of energy. For the production of x-rays this is done by accelerating electrons through potential differences of from ten thousand to a million volts. Since one electron is very small, it can deliver all this energy to a small part of one atom and so produce the intense local disturbance that results in the emission of x-rays. For the disruption of an atomic nucleus still higher concentration is necessary, and it can be produced by accelerating protons, deuterons or alpha particles through large potential differences. However, the production and control of large potential differences are very difficult. There are troublesome problems of insulation, and the corona losses are so dependent upon weather conditions that the most satisfactory devices are enclosed in tanks. A much more convenient method of giving a great deal of energy to a small particle is to subject it to a series of impulses of moderate size. It is in just such a way that an automobile engine operates. A series of explosions, one after the other and occurring at just the correct times, serves to produce a high speed in the flywheel, while an attempt to use a single tremendous explosion, such as takes place in a large naval gun, would be accompanied by a variety of difficulties.

In pursuit of this objective Professor Lawrence and his collaborators built, around 1931, several devices intended to produce high-speed particles. One consisted of a long tube containing a number of cylindrical electrodes through which the particles could pass. Between adjacent electrodes an alternating potential difference was applied, and by an ingenious arrangement of oscillating circuits it was provided that when a particle passed between a pair of electrodes, the potential difference was in such a direction as to accelerate it. When the particle passed through the electrode and out into the space between the next pair, the potential reversed so as to continue accelerating it. This apparatus operated successfully and produced mercury ions of large energy, but it was soon largely abandoned in favor of the device that developed into the large cyclotrons in use to-day.

In the cyclotron, the alternating potential difference is applied to one pair of electrodes only, but the particle, bent

in a magnetic field, is made to go back and forth between them in such a way that the field is always accelerating it and increasing its speed and energy. By this means, with the use of a maximum potential difference of around 150,000 volts, it has been possible to give to particles the same energy as though a total of 18 million volts had been available for acceleration.

The enormous possibilities opened up in the field of nuclear physics by the development of the cyclotron have been universally recognized. In institutions all over the world, and with a particularly high "density" over the United States, cyclotrons have been built and put into operation, and more are under construction. The various instruments at Berkeley have turned out a steady stream of results of importance in the understanding of the structure of atomic nuclei, as well as a variety of products of importance in biological and medical research. It has been found that the bombardment of almost any substance with high-speed protons, deuterons or alpha particles, produces from the original element some other element, often in a radioactive state, a state formerly thought to be entirely beyond the reach of artificial influence. This provides a tremendous mass of material for the study of radioactive processes and the behavior of the nuclei of the atoms thus produced. At the same time these artificially produced radioactive substances have proved of great value as tracers in following the dispersion of various materials through a living organism, as well as in providing a means of getting radioactive radiations really inside the cells of an animal.

In the minds of those acquainted with the situation there is no question but that because of the extensive range of its influence on the development of all branches of science, the cyclotron is to be regarded as one of the most important contributions ever made to the technique of modern physics; and that for the ingenuity of its conception and the skill with which the conception has been carried out the highest credit is due to Professor Lawrence.

W. V. Houston
California Institute of Technology

THE CENTENARY OF THE DISCOVERY OF THE VULCANIZATION OF RUBBER

To celebrate the centenary of the discovery of the vulcanization of rubber by Charles Goodyear in 1839, the American Chemical Society dedicated the general program of its Boston meeting, September 11–15, to discussions of vulcanization and to "the real memorial of this great inventor—the great industry which he founded, whose products have been vital to still greater industries, and have contributed to the safety, comfort and prosperity of mankind." In addition, the Rubber Division held a Symposium on the Vulcanization of Rubber and an exhibit of historic treasures and modern products of the rubber industry.

In the life stories of Charles Goodyear and his English contemporary, Thomas Hancock, is the description of the small, crude business of the early nineteenth century and its transformation to a huge, modern industry based on their discoveries of methods for processing and vulcanizing rubber. When they started their work rubber was a material which promised great things because of its elasticity and resistance to water, but which always failed to fulfil that promise because of its thermoplasticity. Furthermore, sheets and threads had to be cut from relatively small solid blocks, and fabric could be coated only from dilute solutions. Goodyear, Hancock and the pioneers associated with them developed methods for masticating rubber to make it more plastic, cohesive and soluble;

CHARLES GOODYEAR'S DISCOVERY OF VULCANIZATION

AN ARTIST'S CONCEPTION OF THE EVENT AS IT OCCURRED IN THE KITCHEN OF HIS HOME, WOBURN, MASSACHUSETTS, IN 1839.

THE FIRST RUBBER MILL. HANCOCK'S MASTICATOR.

calenders for making large sheets and for coating fabrics: and the method of vulcanizing rubber with sulfur which, for practical purposes, eliminated the thermoplasticity of rubber, made possible the formation of molded rubber goods and made available ebonite, as well as soft vulcanized rubber. The paper on "The Work of Thomas Hancock" was presented by Mr. A. A. Glidden and that on "The Work of Charles Goodyear" was written by Mr. R. W. Lunn, whose attendance was prevented by the war, and was read by Mr. W. B. Wiegand. In addition, the inventors were allowed to tell their own fascinating stories through the presentation at the banquet of a single volume containing facsimile

TIRES—OLD AND NEW.

STATUE OF CHARLES GOODYEAR, TRIBUTE TO INVENTOR OF VULCANIZATION
BY GOODYEAR TIRE AND RUBBER COMPANY, ON THE 100TH ANNIVERSARY OF THE DISCOVERY. THIS STATUE STANDS IN FRONT OF AKRON CITY HALL.

copies of "Gum Elastic" by Goodyear and "Personal Narrative" by Hancock.

The papers of W. A. Gibbons, J. M. Bierer and P. W. Litchfield describe the technical and industrial growth of the industry to its vital position in modern civilization.

In discussing "Lessons from the Past," President Conant emphasized the frequently forgotten fact that scientific progress is greatly helped by industrial progress and that the trend of science is influenced to a large degree by the social and economic environment. President Compton told of the effect of synthetic chemistry in removing "the need for employing armies and navies to acquire the world's natural resources" and predicted an accelerated rate of scientific discovery.

At the symposium on "The Vulcanization of Rubber" the technical descendants of Charles Goodyear discussed the progress of their attack on the problem which was revealed by his discovery of the phenomenon. Here, as elsewhere, the lonely pioneer has been replaced by an army with modern weapons of chemistry, physics and botany.

PORTRAIT OF GOODYEAR
AND AN EBONITE TABLE MADE BY HIM.

The technical importance of vulcanization is due to the physical changes induced by it—reduction of plasticity, increase in tensile strength, fatigue life, resistance to oxidation and the stabilization of these properties to both higher and lower temperatures. These changes are all affected by the use of such compounding materials as accelerators, activators, fatty acids, reinforcing pigments and age resisters, as well as by the temperature of vulcanization and the variability of plantation rubber. A number of vulcanizing agents other than sulfur have been discovered, and Dr. Fisher reported that he has obtained good vulcanizates by the use of age resisters with oxidizing agents. In comparatively recent years the use of rubber latex has grown to large proportions and a big industry has grown up based on "devulcanizing" or reclaiming of vulcanized scrap. All these various problems were discussed from the view-point of chemical reactions, physical structures, thermodynamics, x-ray studies, electrical properties and technical utility.

Since an understanding of vulcanization requires an understanding of the structure of rubber and the mechanism of elasticity, it was natural that these subjects should also be discussed.

Synthetic rubber, long of scientific interest, has become of practical interest because of the development of oil resistant rubbers in the past decade. The outbreak of war in Europe and its possible effect on the supply of so strategic a material as rubber greatly stimulated this interest. Consequently, in addition to formal papers on synthetic rubber-like materials and the preparation of butadiene from petroleum, there was considerable corridor discussion of the manufacture and use of various types of synthetic rubber.

B. S. GARVEY
CHEMICAL RESEARCH LABORATORIES,
THE B. F. GOODRICH COMPANY

OPENING OF THE BUHL PLANETARIUM AND INSTITUTE OF POPULAR SCIENCE IN PITTSBURGH

WITH the opening of its "Hall of Light" in early January the new Buhl Planetarium and Institute of Popular Science, in Pittsburgh, was in complete operation. At the same time, the workrooms for amateur astronomers, where they can construct their own telescope mirrors and mountings, were made available for members of the Amateur Astronomers Association of Pittsburgh.

The other sections of the institute opened with ceremonies held in late October. These included the "Theater of the Stars," equipped with the fifth Zeiss planetarium in the United States, the "Hall of Astronomy," a number of exhibits relating to chemistry and physics in the main entrance hall, a large gallery for temporary exhibits and a lecture hall.

The entire institution is a memorial to the late Henry Buhl, Jr., Pittsburgh merchant, who died in 1927 and, by his will, established the Buhl Foundation. Chatham Village, a housing project that has attracted attention internationally, research programs, historical publications and many other educational activities have been sponsored by the foundation, which made a grant totaling about $1,100,000 for the erection and equipment of the new institute.

The limestone building was designed by Ingham and Boyd, Pittsburgh architects, and is decorated with six sculptures by Sidney Waugh, of New York. It is located on the city's North Side, which was the city of Allegheny before the consolidation with the city of Pittsburgh, which took place in 1907. In fact, the site is the one formerly occupied by the Allegheny City Hall. In addition to being central, the location is particularly appropriate in several ways. Mr. Buhl's business life was centered in this section of the city. Not far away is the Allegheny Observatory, with its long record of valuable researches under the directorship of such famous astronomers as Langley, Keeler, Schlesinger, Curtis and Jordan. This was also the region where lived and worked the well-beloved "Uncle John" Brashear, telescope maker and popularizer of science.

Opposite the building is Ober Park, which has been redesigned in keeping with its new environment. On one side is the Carnegie Library, on the other the Post Office, while a short distance away stands the new Allegheny General Hospital. Ten street-car lines pass the building, and seven others come within a block, so that it is easily accessible from all parts of the city.

Entering the building through revolving doors from West Ohio Street, the visitor is in the middle of a large hall, 32 feet deep and 148 feet wide, and with a ceiling 27 feet high, with terrazzo flooring and a wainscoting of Sienna marble. This gallery, like all the exhibit halls,

DOORWAY OF THE BUHL PLANETARIUM

THE NEW BUHL PLANETARIUM AND INSTITUTE OF POPULAR SCIENCE

has no windows, which makes for complete flexibility in arrangement of exhibits. Towards one end hangs the Foucault Pendulum to demonstrate the Earth's rotation, while to the other end of the hall is a large rotating drum showing a Periodic Table of the Chemical Elements, with samples of almost all of them and surmounted by a revolving globe of the Earth. Around the Foucault Pendulum are grouped a number of exhibits relating to physics, especially electricity, and around the Periodic Table are chemical displays. One of these shows the growth of plants under artificial light, and with nutrient solutions in place of soil.

From the west end of the main hall, one enters the Lecture Hall, seating 250 persons and equipped with complete projection equipment for silent and sound motion pictures, in 16 and 35 millimeters, and for lantern slides. At the front is a lecture table with all needed facilities. Like other parts of the building, the lecture hall is air-conditioned.

In a corresponding position, at the east end of the building, is the Hall of Astronomy. The wall at the far end shows an arc of the Sun and the planets to the same scale. Below are diagrams showing the orbits of the planets and five scales with dials to show what one's weight would be on Eros, the Moon, Jupiter and the Sun, as well as on the Earth. Along the walls are exhibits showing methods of time determination and time-keeping, and observatories of the past and present. Other displays illustrate motions of the stars. In the center of the room are shown a group of medals and cups presented to John A. Brashear and a collection of meteorites. One of these, weighing nearly 700 pounds, is arranged to tell its own story. When the visitor presses a button, a record is started in another room and a

ENTRANCE GALLERY OF BUHL PLANETARIUM IN SIENNA MARBLE

spoken explanation is heard. By an intricate wiring system, exhibits in all parts of the building may be made to tell their own stories in the same way.

Through the middle of the Main Hall is the entrance to the "Theater of the Stars," the planetarium chamber, 65 feet in diameter, and provided with a perforated metal dome, which has proven to be the best for the purpose. The planetarium projector, for the first time, is mounted on an elevator, so that it may be removed completely from the chamber and the floor covered. This makes possible greater realism, for the room can be darkened without the audience being conscious of the machine. It also permits greater latitude in giving special performances, for which there is a stage. This, too, is removable. A section of the wall opens, and the stage can be rolled out, by electric motors, into the room. Complete air-conditioning keeps the chamber comfortable. Full projection equipment for slides and motion pictures, apparatus for recorded music and an electric organ are also provided and used regularly. The room has seats for 492 spectators.

Two wide stairways from the Main Hall conduct the visitor to the lower floor. First he reaches a mezzanine, and from this he can go into an octagonal room below the planetarium chamber. This is devoted to temporary exhibits. For the first few months it was a "Hall of Safety," with tests for safe driving, provided by the Aetna Casualty and Surety Company. Later it will be used for an exhibition of photography and for a School Science Fair, with scientific exhibits made and shown by high-school students.

At the front of the lower floor, under the Main Hall, is the "Hall of Light," with exhibits showing the spectrum, the stroboscope, fluorescence, formation of images by mirrors and lenses, etc. As

in other halls, most of these exhibits are action ones, operated by the visitor. Several are equipped for spoken descriptions. Adjoining the hall of light at one end are the workshops of the Amateur Astronomers Association. At the opposite end is a "Club Room" for meetings of a hundred or less. The rest of the ground floor is devoted to the mechanical facilities of the building, air-conditioning, machine and woodshops, photographic laboratories, etc.

The offices are on the second floor, and on the third floor is space for an observatory, which will be opened in the late spring. This will be provided with a 10-inch siderostat telescope, made by the Gaertner Scientific Corporation of Chicago. Having a fixed eyepiece, used from a closed observing room, while the telescope lens and the flat mirror feeding it are in the open, this is an ideal type of instrument for a public observatory. Because of the importance of the Pittsburgh area in science and technology, it is felt that the Buhl Institute will fill an important place in the community. By continual change of exhibits and demonstrations, it is believed that the steady interest of the people will be aroused. Scientific demonstrations and showings of scientific motion pictures will be given in the lecture hall. In the Theater of the Stars, full use of the stage and other facilities will be made to dramatize the subjects presented, and thus to interest a section of the community which might otherwise remain aloof. Outstanding displays of industrial science will be shown in the Octagonal Gallery. The Hall of Light will not be permanent, but will later give way to correspondingly complete display of some other branch of science, such as radiation, in general, or perhaps some subject relating to chemistry or biology.

Admission is charged to the planetarium, but the exhibits in the various halls are free. The admission will be the main source of income. The institution is under the control of a board of managers, consisting of the four members of the Buhl Foundation board—William S. Linderman, Arthur E. Braun, Andrew W. Robertson and Colonel Charles A. Brooks—Dr. Charles F. Lewis, director of the foundation, who is the president, and, *ex-officio*, the mayor of Pittsburgh and a representative of the city council. The Honorable George E. Evans fills the latter post.

JAMES STOKLEY,
Director

MORE SPEED IN CAMERA LENSES

AN enormous amount of progress has been made in the speed with which photographs can be taken since Daguerre startled the world with his first pictures a hundred years ago. His wet plates were followed by the much more convenient dry plates, which have become increasingly sensitive and rapid. Indeed, since the great 200-inch telescope was started the increase in sensitivity of photographic plates, especially for red light, has made the old 100-inch Mt. Wilson telescope nearly as effective for celestial photography as it was expected the larger new telescope would be. In other words, the speed of photographic plates, especially for red light, has more than doubled in about five years.

The speed of a camera or other photographic instrument depends also upon its objective, or the lens which gathers the light. Obviously the brightness of the image on the photographic plate is proportional to the area of the objective; that is, to the square of its radius. For this reason the objectives of the portrait cameras before the advent of modern sensitive plates were generally several inches in diameter. The 200-inch telescope is being constructed at a cost of

about $6,000,000 because of its great light-gathering power.

The image formed by an objective is obviously brighter the smaller it is—the same amount of light on a smaller area. The image is smaller the shorter the focal length, in area inversely as the square of the focal length. For this reason cameras of continually decreasing ratio of diameter of objective to focal length have been produced. Other things being equal, a camera whose focal distance is twice the diameter of its objective is four times as fast as one in which the ratio is four to one.

Objectives of short focal length meet a serious difficulty—the curves of their lenses must be steep. The steeper they are the greater their aberrations and the greater the number of lenses that must be employed to correct the defects. The lenses of nearly all cameras consist of at least three lenses; those of very short focal ratio, of at least five lenses. At each surface of these lenses there are reflections, the more serious the steeper their curves. These losses are so great that a camera objective of five lenses transmits to the photographic plate under the most favorable conditions only about 60 per cent. of the light that falls upon it. The remainder is not only lost to the image but is scattered, and part of it produces spurious effects upon the plate.

Recently Dr. C. Hawley Cartwright, of the Massachusetts Institute of Technology, has greatly reduced the reflections from the surfaces of compound objectives. Indeed, for the focal length ratio of two to one in five-element objectives he has doubled the speed. The underlying principle used is that losses by reflection are reduced when lenses are covered with very thin layers of transparent media of low refractive index. The thickness of the layers is of the order of half of the wave-length of the light it is desired to transmit as completely as possible.

Such substances were found by Dr. Cartwright in the metallic fluorides. Unfortunately, the films of these materials can be deposited on the surfaces of lenses only in a vacuum, a fact that adds considerably to their cost. Yet in quantity production the costs will doubtless be reduced until the lenses of all high-grade cameras will be coated with thin films—indeed, microscopically thin films—having the properties of transparency and low refractive indices. In this new way another important step will be taken in increasing the speed of cameras.

F. R. Moulton

HOUSE-HEATING BY SOLAR ENERGY

For many years scientists have been interested in the problem of using radiant energy received from the sun as a source for heating and mechanical work. Dr. Charles G. Abbot, director of the Smithsonian Institution, has constructed a series of notable solar engines that have attracted much attention. Now the Massachusetts Institute of Technology has taken up the problem of house-heating by solar energy with the aid of a gift of nearly $650,000 from Dr. Godfrey L. Cabot.

Enough solar energy is received each year on nearly any building, even a manufactory, not only to heat it but to operate all the machinery it would contain. Expressed in terms of horsepower, the energy received by the earth from the sun amounts, on the average, to about three eighths of a horse power per square yard. Of course, the amount received depends upon the latitude, but it does not vary as much as is generally supposed. For example, at the earth's equator the amount of solar energy per

unit area received per year is only about 2.5 times as much as is received at the poles, though the distribution differs widely throughout the year.

The amount of solar energy received by any place on the earth varies each day from zero (except in polar regions) to a maximum depending on the latitude and the time of the year. In order to have available an unfailing and uniform supply, some effective and feasible storage system is necessary. Lest it be feared that the energy received from the sun would not be sufficient, even if it could all be used, to heat a residence, it may be remarked that on a house 30 by 36 feet (10 by 12 yards) in floor dimensions solar energy is received, on the average, at the rate of 45 horsepower. This energy for 24 hours is approximately equivalent to the total energy in 160 pounds of good coal. Since no house 30 by 36 feet in dimensions uses, on the average, more than 160 pounds of coal a day, solar energy is sufficient for house-heating in mid-latitudes providing it can be efficiently stored and used.

How can energy be stored? Theoretically there are many ways—as heat, as chemical energy, as electric energy, as potential mechanical energy. For various reasons the storing of energy in the form of heat is the most promising. All that is necessary is to provide something that will absorb solar energy as heat when the sun shines, store it safely and economically, and deliver it whenever it may be required. For very good reasons the scientists at the Massachusetts Institute of Technology have chosen water as the material in which to store energy. In the first place, water is cheap, easily handled and safe. In the second place, more heat is required to raise the temperature of a pound of water a given amount than to raise the temperature of a pound of any other solid or liquid the same amount. And conversely, in giving up a certain amount of heat the temperature of a pound of water is lowered less than the temperature of a pound of any other solid or liquid is lowered in giving up the same amount of heat. For example, the temperature of iron would be lowered five times as much as the temperature of water. Consequently, water is the ideal material for storing heat without using high temperatures.

Obviously, the problem of getting solar energy into water and preventing its escape until it is required is a serious one. It can undoubtedly be solved provided we will pay the cost. There is no prospect that at present solar energy can be used for such purposes as house-heating in competition with coal and petroleum. But eventually coal and petroleum will be exhausted, last in North America because this continent contains a considerable fraction of the known petroleum resources of the world and over half of all the coal. Long before that time comes scientists will have found other sources of energy, the most promising of which is the sun, from which essentially all terrestrial energy has directly or indirectly been received. For example, it is solar energy that raises water to high levels in the air, that drives the winds that turn our windmills and fill the sails of our ships, that is stored up by photosynthesis in the myriad chlorophyll cells of plants, some of it later to be available as food or coal or petroleum.

F. R. M.